SCHOOL SCIENCE AND MATHEMATICS

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DEPARTMENT OF RESEARCH IN PHYSICS.

The Council and the Educational Committee of The American Physical Society are working on the problem of helping high school and college teachers of physics to advance in their field and to benefit by the work of research physicists. They are recommending a liberal use of this department as one means of attaining their end. Articles will be contributed by members of the Physical Society, most of whom are actually engaged in the research work. If physics teachers will write to the editor of this department and tell him of their particular needs, of their interests and, also, of their reaction to the articles that appear, he will be better prepared to present this work to the American Physical Society and to appeal to its members for assistance.

The following paper appeared in the January, 1923, number of the Bell Telephone Quarterly and is printed here by permission of R. W. King, author of the article and editor of the Bell System Technical Journal.

ELECTRIC WAVES—THE MODERN MERCURY.

By R. W. King, American Telephone and Telegraph Company, Bell System, 195 Broadway, New York City.

All intelligence is brought to us by waves of one form or another. Hearing and sight are the familiar illustrations, one depending upon air waves and the other upon the so-called ether waves. The telephone and telegraph, whether wire or radio, are equally good examples. Like the sense of sight they depend upon ether waves. In the radio telephone and telegraph the waves bearing messages spread out through space in all directions; in the wire telephone and telegraph they travel very close to the line wires which serve as guides between the sending and receiving points.

The familiar expression is that the electric "current" transmits telephone and telegraph messages. This is only a partial picture. An electric current in a wire implies the presence of electric waves

in the region surrounding the wire, and physics teaches that the energy of the "current" is to be found in these waves. This conception of the transmission of energy is deducible from Maxwell's fundamental postulates and will be found elaborated in the writings of Poynting, in 1884, J. J. Thompson, in 1893, and Heaviside, in his Encyclopedia Britannica article in 1902. When a current of electricity flows in a wire it represents the drawing of energy from the surrounding ether waves, and if the current could be prevented the waves would travel with less tendency to die away.

The extent to which wires act as guides for the energy of the electric waves may be illustrated by a long open-wire telephone circuit. From Fig. 1, showing a section of such a circuit, it is seen that the ether immediately around the wires acts like a sort of duct through which the energy passes.

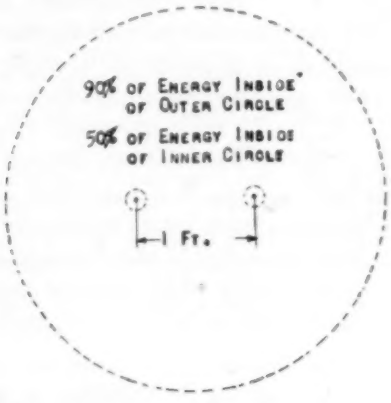

FIG. 1. ENERGY DISTRIBUTION WITH NO. 8 B. W. G. OPEN LINE CIRCUIT CARRYING A. C. CURRENTS

Electric waves used in telephony and telegraphy, both wire and wireless, belong to the same category of ether waves as the light waves of the visible spectrum and the infra-red, ultra-violet, and X-ray spectra. They are, however, of much higher frequency. The relative frequencies of the principal portions of the ether wave spectrum thus far studied and classified are given in Table I. At one end lie the extremely short X-rays whose wave lengths are of the order of a billionth of an inch, a distance that is comparable with the distance between the atoms of most crystals. At the other extreme come the very long waves used in electrical communication whose lengths range all the way from many feet to many miles.

TABLE I

	Frequency in Cycles per Second
Wire transmission systems	0 to 30,000
Radio	15,000 to 10^7
Hertzian Waves	10^7 to 10^{10}
Infra-Red	10^{12} to 4×10^{14}
Visible	4×10^{14} to 8×10^{14}
Ultra Violet	8×10^{14} to 3×10^{15}
X-Rays	about 3.5×10^{17} to 5×10^{18}

The view that all ether waves are fundamentally alike—whether X-rays or the long waves used in communication—originated in the theoretical work of Maxwell and the experimental work of Hertz. Notwithstanding the fact that every wire carrying an electric current is surrounded by long ether waves, their existence became known only when Hertz succeeded, so to speak, in shaking them loose from their wire paths making them free to radiate in all directions. Because they originate about an electric circuit they are frequently referred to as *electric* waves, but the very much shorter waves of light are as truly electrical in origin.

So far as is known, all ether waves travel with a common speed, namely, 186,000 miles a second. This speed has been accurately measured for the waves of the visible spectrum and also for the long Hertzian waves. The speed of X-rays has not as yet been directly determined but there is no reason to believe that they form an exception to the general rule.

The question is frequently asked and seldom answered correctly as to the speed at which telephone and telegraph messages travel over long circuits such as that between New York and San Francisco or a submarine cable under the Atlantic Ocean. As a matter of fact the answer is very simple. As already pointed out the electric waves travel along the wire or cable with the speed of light. On this basis, the waves constituting a telegraph message would require less than 1/50 of a second to travel from New Foundland to Ireland, a distance of about 2,800 miles. This does not mean, however, that the message sent from New Foundland will be *reproduced* at the receiving station on the Irish coast within 1/50 of a second. The reproduction of the message requires movement on the part of the receiving instrument and this in turn depends upon the building up of an appreciable electric current in the receiving end of the cable. It is the building up of the current and the production of motion which requires time. In the case of the Atlantic cable some *three* or *four* seconds is required.

To put this another way, a telegraph or telephone message represents a case in which "coming events cast their shadows before." Along the surface of the wire and outside of it, the electric impulses or waves travel with the speed of light. After the initial impulse has passed, current in the same direction as this impulse proceeds to build up. The rate at which the growth occurs depends upon the electrical characteristics of the circuit, it being much slower in a submarine cable than in an open wire telephone or telegraph line. With the lapse of more or less time after the initial impulse, the current in the wire becomes large enough to operate the receiving instrument whether this be a telegraph sounder, a telephone receiver or a syphon recorder.

One of the most characteristic phenomena connected with wave motion is that of "resonance." Doubtless everyone has at some time made the acquaintance of a piano which attempts to talk back to him. This effect can be secured from any piano by lifting the dampers from the strings by means of the sustaining pedal. When free to vibrate, each string tends to be set into sympathetic vibration by those sound waves of the voice which correspond to its particular frequency. By gently pushing down a single key on the piano so as not to cause the string to vibrate and then singing that note, a very good illustration of sympathetic vibration or resonance is obtained. By holding down several keys and singing only one of them it will be found that that one alone responds by resonance. This gives a very simple illustration of the principle of "tuning" as practiced in radio telephony and telegraphy. Carrying out the analogy, each string may be looked upon as a radio receiving station, only that single one being set into motion whose rate of vibration is the same as that of the sending station.

What is more natural than to attempt the transmission of several telegraph messages over a single wire at the same time by employing this principle of resonance? As much as fifty years ago, we find that two notable attemps were made to develop an "harmonic" telegraph. About 1872 Elisha Gray and Alexander Graham Bell independently set out to solve the problem, making use of mechanical resonance as displayed by vibrating strings and reeds.

Gray succeeded in bringing his invention to a remarkably high state of perfection but it did not prove capable of the important practical applications for which he had hoped. Bell, on the other hand, encountered difficulties and digressed from his original plan

due to certain curious observations which he accidentally made. He failed to complete his device but by digressing he came upon another very useful invention, the telephone. He had for some time had visions of a device for transmitting speech electrically, and when he detected what he thought was a clue to it in his accidental observations, he straightway bestowed all of his energies upon it.

The fundamental properties of all wave motion, whether found on the surface of water, or in the air, or sounding bodies, or in the ether of space, are practically identical. This does not mean that sound waves in air and electric waves in the ether are identical. It means that the mathematical equations which the physicist uses in his study of these two kinds of waves are similar.

A partial justification of this statement is found in the fact that the phenomenon of resonance as displayed by sounding bodies is paralleled accurately by resonance in electric circuits. The "tuning" of a wireless receiving set consists simply in changing its natural rate of electrical vibration so as to be equal to the rate of some station which is sending out messages. When so tuned, it is relatively sensitive to the wave length sent out by this station and relatively insensitive to stations transmitting on other wave lengths.

With the discovery of electrical resonance and its close parallelism to mechanical resonance, there came renewed efforts to develop an harmonic telegraph. Naturally the new attempts involved the principle of electrical tuning as a substitute for the mechanical tuning used by Gray and Bell. About the year 1893, Pupin and John Stone. Stone, an engineer of the American Bell Telephone Company, began working upon a system of harmonic telegraphy involving electrical tuning. Its fundamental idea was that the dots and dashes of the telegraph code should be carried by relatively high frequency currents, the simultaneous messages being each carried by a different frequency. Except for the fact that these high frequency currents were to be guided by wires and not radiated in all directions into space, the underlying principles were the same as those at present employed in wireless telegraphy.

About the same time Stone, in this country, and Messrs. Hutin and LeBlanc, in France, were attacking the problem of what might be called an harmonic telephone. Just as in the telegraph the effort was to carry dots and dashes by alternating currents of frequencies ranging from about 200 to 500 cycles per second, the seekers after the harmonic telephone proposed to carry the rapid fluctuations of the voice by alternating currents of higher fre-

quencies between 10,000 and 20,000 cycles per second. By the use of several such high frequency currents they hoped to transmit several telephone messages at once over a single pair of wires. Like Pupin, they made use of tuned circuits and electrical resonance. These pioneers in the field of harmonic telephony—or "carrier current" telephony, as it is known today—were able to make their inventions work under favorable conditions but they proved too delicate, too unreliable, to be practicable for public use. Although means were provided for the simultaneous transmission of several messages over a single circuit, the complications involved over-balanced any advantages that the multiplex feature might have.

An explanation of the failure which met the efforts of these pioneer investigators is found in the undeveloped state of the art of transmitting currents over wires which prevailed at that time. In the light of our present-day knowledge we see that the solution of harmonic telephony demanded certain devices which were not then to be found even in the imaginations of the foremost investigators. Nor were these essential devices immediately forthcoming; for during the years 1906 to 1911 a number of workers, among whom may be mentioned Vreeland, Squier and Alexanderson in this country and Ruhmer in Europe, suggested multiplex carrier telephone and telegraph systems which employed the same fundamental principles previously worked upon by Pupin, Stone and others and with no better success.

The successful application of carrier currents has been a development of the past four or five years and looking backward, we can now see the factors that have turned failure into success. The most important of these are three in number:

1. Development of the familiar vacuum tube to such a state that it is a reliable and stable instrument for amplification, detection and modulation of electric currents.
2. Development of a device known as an electric wave filter which represents a vast improvement over the tuned circuit as a means of separating electric currents of different frequencies.
3. Development of the technique of transmitting telephone and other currents over wires, with particular reference to telephone repeater operation and the methods of overcoming interference or "cross-talk" between adjacent circuits.

These developments have emanated from the research laboratories of the Bell Telephone System, and indeed could scarcely

have been possible except through the close cooperation and the careful dovetailing together of almost countless individual pieces of research which a large laboratory organization makes possible.

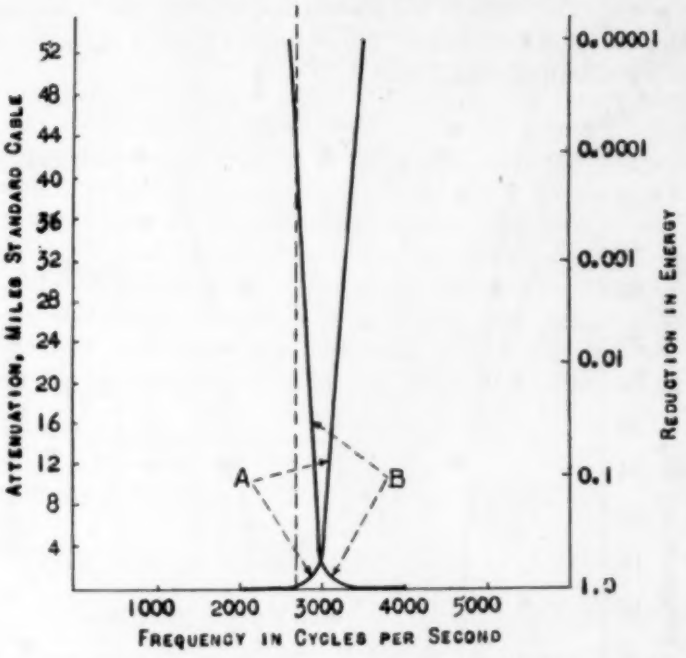

FIG. 2. TRANSMISSION CHARACTERISTICS OF "LOW PASS" FILTER (CURVE A) AND "HIGH PASS" FILTER (CURVE B).

The electric wave filter is one of the most remarkable developments of recent years in the field of electric circuits. The filter makes it as easy to separate alternating currents of different frequencies as screens with different sizes of mesh make possible the separation of stones and gravel of different sizes. It is the invention of Dr. G. A. Campbell of the American Telephone and Telegraph Company and were it not for the unfortunate fact that any comprehensive understanding of its action involves quite a bit of higher mathematics, it doubtless would be much more widely known today than it is.

The filter does not respond to electric currents in the same manner as the tuned circuit. It acts as a gate which can be placed in any circuit and which will admit only currents of predetermined frequencies. For example, a filter can be designed which will admit currents from zero frequency to any higher frequency such as 200 cycles. Or the filter may be designed to

admit all currents between two definite frequencies as, for instance, 200 cycles per second and 500 cycles per second. Or again, it may be designed to admit all currents above a certain frequency. These filters are known respectively as "low-pass," "high-pass" and "band-pass" filters and the general characteristic of each is shown in Figs. 2 and 3.

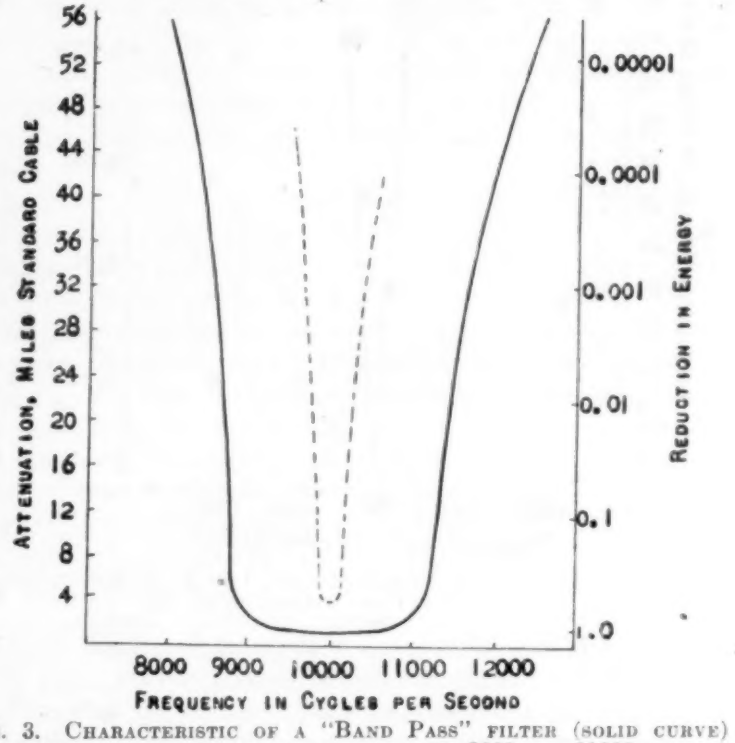

FIG. 3. CHARACTERISTIC OF A "BAND PASS" FILTER (SOLID CURVE) DESIGNED TO ADMIT FREQUENCIES BETWEEN 9000 AND 11000 COMPARED WITH THAT OF A RESONANT CIRCUIT (DOTTED CURVE).

The selectivity of the filter as shown by the solid line in Fig. 3 is remarkably uniform over any range of frequencies for which it may be designed—in Fig. 3 this range is from 9,000 cycles to 11,000 cycles. For comparison, the selectivity of the resonant circuit is shown by the dotted curve and, as will be seen, is great in the immediate neighborhood of 10,000 cycles but diminishes rapidly on either side.

The manner in which filters are used in a modern carrier telephone circuit is shown diagramatically in Fig. 4. Each telephone channel must supply means of transmitting speech in both directions. This is generally accomplished by using a different carrier frequency to transmit in each direction. In our diagram the

lowest carrier frequency has been taken as 10,000 cycles per second. When this is modulated with speech it becomes a band of frequencies ranging from 10,000 cycles to about 12,500 cycles because the band of speech frequencies is itself about 2,500 cycles wide. The next carrier frequency must, therefore, be somewhat greater than 12,500. In our illustration it has been chosen as 13,500. This in turn when modulated with speech becomes a band of frequencies ranging from 13,500 to 16,000. The next carrier channel runs from 17,000 to 19,500. As shown in the diagram these three channels carry speech from west to east. To carry it from east to west three other channels running from about 20,000 to 30,000 cycles are employed. In this way the likelihood of the westbound channel A cross-talking into eastbound channels B or C is reduced to a minimum. This is a very important point for, as already indicated, the elimination of cross-talk be-

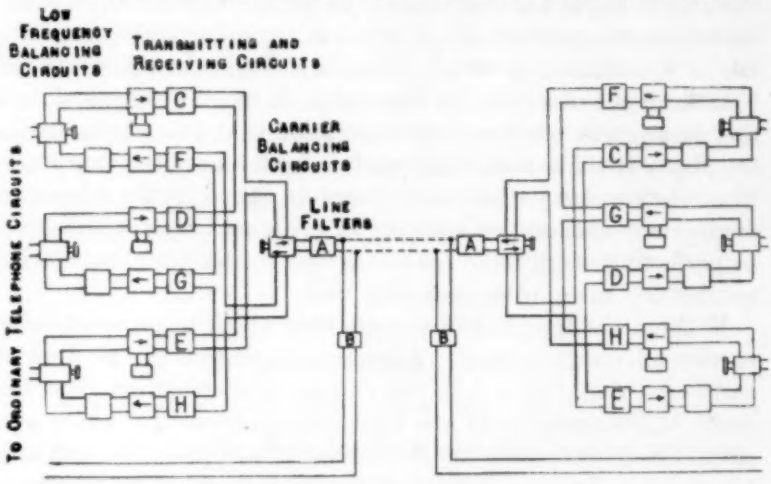

FIG. 4

A, BAND-PASS FILTERS ADMITTING ALL CARRIER FREQUENCIES BUT EXCLUDING THE BAND OF VOICE FREQUENCIES.

B, BAND-PASS FILTERS ADMITTING THE VOICE FREQUENCIES BUT EXCLUDING ALL CARRIER FREQUENCIES.

C, BAND-PASS FILTERS COVERING THE RANGE FROM 10,000 TO 12,500 CYCLES.

D, BAND-PASS FILTERS COVERING THE RANGE FROM 13,500 TO 16,000 CYCLES.

E, BAND-PASS FILTERS COVERING THE RANGE FROM 17,000 TO 19,500 CYCLES.

F, BAND-PASS FILTERS COVERING THE RANGE FROM 20,000 TO 22,500 CYCLES.

G, BAND-PASS FILTERS COVERING THE RANGE FROM 23,500 TO 26,000 CYCLES.

H, BAND-PASS FILTERS COVERING THE RANGE FROM 27,000 TO 29,500 CYCLES.

tween adjacent carrier circuits has been one of the most difficult problems for the telephone engineers to overcome in arriving at a successful carrier system.

Of equal importance with the filter has been the development of a successful telephone repeater. This, as is generally known, employs the three-electrode vacuum tube as one of its integral parts. The rise of the vacuum tube to a position of importance in the electrical art has been extremely rapid. It first assumed commercial importance by its use in the telephone repeaters of the transcontinental telephone line when that was opened in 1915. The studies which were made by the telephone engineers to adapt the vacuum tube to long distance telephony in the transcontinental line demonstrated that this remarkable device could also be made the keystone of a practicable radio telephone, and the development of power vacuum tubes very much larger than any theretofore made was immediately undertaken. With these tubes speech was successfully transmitted in the fall of 1915, from the city of Washington across the Atlantic to Paris and also westward a distance of 5,000 miles, to Honolulu. It was the success of this first large radio telephone demonstration that proved that radio telephony could be made sufficiently reliable for military purposes. Many new investigations were therefore begun by the telephone engineers in cooperation with the U. S. Signal Corps, with a view to perfecting small radio telephone sets for air-craft, submarine patrols and many other war-time uses.

Without the telephone repeater there would be no practicable carrier telephone system. Some experimenters in the field of carrier currents have had the curious misconception that the mode of transmission of the high frequency electric waves employed in carrier operation is different from that of the ordinary telephone and telegraph frequencies and that the carrier frequencies have some unexplained property whereby, although guided by the line wires, large energy losses in the wires are avoided. There is, however, no theoretical or experimental justification for this idea. As a matter of fact, a high frequency carrier current tends to die away more rapidly in traveling over a long line than does the ordinary telephone current. The higher the frequency the more rapidly does it die away.

To indicate the importance of telephone repeaters in a carrier system it may be stated that if the Harrisburg-Chicago carrier telephone line, 750 miles long, were operated without repeaters it would be necessary to apply at the sending end a power of 60

kilowatts; by the use of intermediate repeaters the power at no point exceeds 1/600000th of this figure, or 1/10 watt. Since the difference between the two cases is represented by a factor of 600,000, it need scarcely be added that without telephone repeaters the carrier system would be utterly impracticable except perhaps on very short circuits. On short circuits, however, it is cheaper to provide additional line wires than to resort to the complications which are necessarily involved in the carrier system.

One of the most interesting and noteworthy features of the development of harmonic or carrier current telegraphy and telephony has already been hinted at. Upwards of half a century ago two inventors—one of them the subsequent inventor of the telephone—strove to perfect a harmonic telegraph. They were both men of vision—of vision so keen and far-sighted that they attempted what would ultimately come to be of great service, but which was far in advance of the electrical art of their day. The art had not then dreamed of the essential stepping stones by which the desired end was to be reached—the vacuum tube and the filter. By the development of these and countless other and less conspicuous improvements in the transmission of communication currents over wires, the telephone engineers of today have reached the goal for which the inventor of the telephone strove and by which efforts he was led to the telephone itself.

PHYSICS AS A CAREER.[1]

By George Walter Stewart,

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It is said of the famous Clerk Maxwell that throughout childhood he continually asked the questions, "What's the go of that? What does it do?" Vague answers did not satisfy him but aroused the more distinct demand, "But what's the *particular* go of it?" Maxwell had the opportunity of devoting a life to the answering of this question, many times repeated, and of rendering such service to mankind that he will be forever highly honored among those known for their important contributions to the field of physics. Do the incipient Maxwells of today have in America a similar opportunity? They do, but there is danger that this fact is either unknown to them or not known sufficiently early in life.

[1]Reprinted from Science, pages 375-378, Vol. LVIII, No. 1502, October 12, 1923.

A boy does not know of a physicist in his community and the stories of achievement in physics which he may read refer to very distant realities. Moreover, so far as he is aware, physics is not a profession. As he surveys his known opportunities for a life-work, engineering may be the only profession that seems to have an interest in the "particular go" of things. The purpose of this article is to present briefly and with directness the opportunities in physics in our country today. It is assumed that, given the possibility of earning a livelihood, one will choose the career which most nearly satisfies his intellectual requirements. Since the aptitude for physics is usually distinct, a comparison of the profession of physics with others is thus unnecessary. The following statement is intended merely to give one who is already interested an assurance that there is an opportunity for the physicist which is limited only by his ability.

The chief avenues open to physicists are found in education, in industry and in government service. What is the prospect of a permanent demand for physicists in these fields? The number of teachers required for our colleges and universities has grown with the rapidly increasing number of students. From educators we learn that the demand for an increase in educational facilities is not occasioned by a temporary interest, but by a realization of the value of education and by a response accentuated through the adjustment of our educational institutions to the more obvious needs of the people. The growth of our educational institutions is therefore certain to continue to be rapid. The industries, particularly those interested in electricity, have grown with tremendous rapidity and have simultaneously expanded their research and development laboratories. The experience gained has demonstrated the constant necessity of improvement of products, of cheapness and of service. It is therefore reasonable to expect a continual increase in the facilities of these laboratories and in the number of physicists employed. The government laboratories have grown with similar rapidity. Thus in every line of activity of the physicist there is an indication of a permanent demand. The profession of physics is established. A physicist may be a teacher only, he may combine teaching and research, he may devote himself to investigation, to development or to a combination of the two, or he may become an administrator in industry.

Teaching.

Every college student is aware of the compensation in the life

of a professor. He is not handsomely rewarded in money, but he lives simply. His family may be deprived of very expensive pleasures, but his children have opportunities for the development of brain and character that can scarcely be measured in terms of money. The real teacher enjoys thoroughly the opportunity of aiding in the development of the young that come into his class-room. He has a vision of helpfulness and of the indefinite extension of his influence through others. It is frequently the teacher in the college, perhaps an investigator in only a small way, who has the best opportunity to assist young men in finding the professions to which they are best adapted. Also, he is responsible in part for the important contributions to physics made by his former students. This is a part of his compensation.

Teaching and Research.

In the large educational institutions the teacher is an investigator who may select for study whatever field he chooses. He receives no demands from his superiors for results that are of immediate practical importance. He is free to choose for investigation any problem that catches his interest and fires his imagination. His intellectual opportunities are without limiting boundaries, and his attainments are determined solely by his ability. Yet he has the satisfaction of serving also through his teaching, his contributions and his students who subsequently become productive physicists.

Upon industrial as well as purely scientific research depends the future development in the products of industry. So active has been the development of electrical applications that the opportunities for research physicists have increased rapidly. The example set by large industries in the employment of these physicists is being followed by others. In 1921, there were forty or more such laboratories employing physicists. The nature of the need of research may be illustrated by reference to the art of telephony. As perfect as the art is today, the increase in the congestion of business in our great centers and the demand for long distance communication, both telephone and telegraph, have necessitated improvements in transmission undreamed of a few decades ago. Yesterday, conversation between New York and San Francisco was a wonderful achievement. Today it is common-place. The research laboratories have solved the problems in physics involved and the development engineers have adapted the solutions to practical service. But the research laboratories are interested not only in the problems pressing

for immediate solution, but they must, so far as possible, foresee the demands of the future. While the research physicist in an industrial laboratory does not enjoy entire freedom in research, yet the desired applicability of his results supplies a challenge to his best powers and his success gives keen satisfaction. One must not gain the idea that the research laboratories are demanding merely experimental physicists. They employ also mathematical physicists who never experiment. In fact, it is appropriate here to say that every physicist must be a theorist. The subject has become so involved that he must usually depend upon mathematical reasoning to determine the plan and method of his experiments.

Government Service.

The Bureau of Standards is now the greatest laboratory of standardization and allied research in the world. Its physicists are employed for the most part in testing for the various industries and educational institutions of the country. But, at the same time, physicists have there been enabled to make some of the most distinguished of the recent contributions of America to physics. Other bureaus, for example, the Weather Bureau, also employ physicists.

Administration in Industry.

More and more is recognized the value of a scientific or technical training for men in administrative positions in industry. Some of these are in connection with research only, but others are in the business organization itself.

The Financial Compensation.

If this brief article were to discuss the attractiveness of physics as a career, it would present the intellectual appeal as the most and the financial appeal as the least important. But it is assumed that the reader is already more or less aware of the nature of the various compensations enjoyed but needs especially to be informed as to the amount of salary that, at the present time, may be expected by an established physicist. In the colleges of recognized standing, the minimum salary of a professor for the college year of nine months is approximately $2,500. A few receive $2,000 or less; many receive more than $3,000. Of course the scale of living in the community is as important a consideration as the salary itself; yet it is impracticable to introduce living costs into this presentation. In the large universities of the country, a similar position pays from $4,000 to $6,000, with ex-

ceptional higher salaries. In government service the salaries are practically the same as in education. In industry the highly trained physicist, if successful, may anticipate at the end of five or six years a salary of $5,000 or $6,000. There is no upper limit in industry for men either in research or in administration.

Ability.

The desirable inate ability of a prospective physicist is not definitely known in detail and its measurement is even less certain. Comments thereon must hence be somewhat general. The special requirements for a successful teacher, a research worker, a development engineer and an executive in industry need not be described as many of the differences are apparent to the student. But it is well to remark that a career in physics demands not only rigorous thinking but also that type of persistence and patience which is required in any worth-while endeavor. Of course, there is always a chance of an accidental scientific discovery of importance, but it is very much smaller than is commonly believed. It is a matter of interest that no physics research laboratory, industrial, governmental or educational, is organized to encourage especially accidental discoveries. Real contributions may arise through accident, but progress in research is usually by a procedure based upon deductions obtained through analysis. Moreover, the purely experimental physicist is vanishing with the increased complexity of the field, and a student who can not use mathematical methods will find therein an increased difficulty in attaining leadership in investigation in the years ahead. An aptitude for analysis, a noticeable mathematical ability, a deep interest in the "particular go of things" and a courage comparable to that in any profession are essential for the highest success.

Preparation.

The preparation required depends upon the nature of the position. There is a demand for those with a college degree as well as for those who have pursued graduate work and have received the M. A., M. S., or the Ph. D. degree. Research and development require clearness of thought, a knowledge of the field and a confidence that comes through experience in intellectual effort. It is obvious that graduate study will develop these qualities and hence will increase the physicist's value. In education, most college and university positions demand the Ph. D. degree, though a number of minor colleges do not insist upon a

preparation beyond the Master's degree. In industry the difference in preparation is recognized at the outset by a difference in salary. But it is in the long run that training shows its value. It may be said that the more ambitious a physicist the more concerned he should be to secure the best educational preparation possible. The nature of this preparation may be inferred from an earlier comment. The theories upon which researches are based are usually mathematical and the student who wishes the best chance for advancement in his career must emphasize mathematics as well as physics. If one is especially fond of mathematics he may well aspire to become a mathematical physicist. In such a case the mathematical training possible in the requirements for a Ph. D. in physics is not sufficient.There are a number of adequately equipped graduate departments of physics in this country and young men of ability will find available graduate appointments carrying stipends, but which involve no return in service, and graduate assistantships which give an opportunity for self-support. The former is to be preferred, for the combination of teaching and study found in the latter requires a longer period of preparation. The way to the top is not short and an ambitious young man needs to save all the time possible.

In general it is fair to say that high attainment as a physicist is difficult. It is in this difficulty, however, that the challenge and ultimately the joy in success rest. If one goes into business to make money he will seek, if possible, an unlimited opportunity. If one enters upon an intellectual career he desires the opportunity to achieve the highest success of which he is mentally capable. He wishes to be limited by nothing save his own ability and industry. A physicist has just this opportunity. He need not wait for business to grow or clients to appear. He can study and contribute to the most important and fundamental problems in physics of the day. He can, if his researches are published, attain without difficulty nation-wide recognition for what he has accomplished. As a consequence he can not avoid chances of advancement appropriate to his ability. His light is upon a hill and can not be hid.

The purpose of this paper is to present to interested students facts without persuasive enthusiasm, and hence to attract to physics as a career only those whose ability and intellectual ambitions can turn a plain statement of facts into an appeal.

CURRICULUM STUDIES ON THE PLACE OF RADIO IN SCHOOL SCIENCE AND INDUSTRIAL ARTS*.

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PART 2.—A RADIO PRIMER FOR PUPIL AND TEACHER.

VIII. What Set Shall I Build?

(Continued from March issue.)

In this section an answer is given to the question, What is the best receiver to build in school science and industrial arts classes? Newspapers and magazines have published the details of so many "best hook-ups" that the school boy and his teacher find it almost impossible to make an intelligent selection.

Unless one has had a great deal of experience in the construction and operation of radio receivers he is unable to judge the relative merits of a "hook-up" or a finished receiver. This work has involved much time and money, in experimentation, in the search for a satisfactory school receiver. The conclusions reported are based not only upon radio construction but also upon many years of experience in other types of school construction work.

Teachers and school executives frequently ask, Where in school work should radio construction be introduced?

It has been found that exceptional pupils only in grades six and seven can be successful in radio construction of the type described here. Pupils below these grades should attempt much more elementary work such as the construction of a crystal set. Some eighth grade pupils have constructed the receiver described below successfully but in our judgment this type of work is done satisfactorily only by high school pupils.

The unusual merits of the Roberts' receiver have been described in several magazines and newspapers and hence are not repeated here. However we have found that few sets having less than twice as many tubes will equal it in performance for quality, distance, or selectivity.

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†Practically all of this work was completed while the author was a member of the staff of the Lincoln School.

FIG. 29. THE FIRST ATTEMPT OF A BIOLOGY TEACHER.

IX. IMPROVED DIRECTIONS FOR THE BEGINNER.

While we found the magazine articles on the Roberts' circuit to be of more value than all previously-used construction articles combined, we also found as a result of experience in supervising the work of pupils and teachers, that a considerable simplification of directions was necessary, especially with respect to pictorial methods for giving instructions. The suggestions in part 2 are the result of several attempts to formulate more useful directions for the construction of this efficient receiver.

X. SELECTION OF PARTS.

To say to the reader, unfamiliar with radio equipment, that the parts should be of good quality, means little. But, as a chain is no stronger than its weakest link, so to a marked degree a radio set is no better than its poorest part. Insulating material, tube sockets, condensers, panels, and binding post strips should be of excellent quality. Contact points should be good; the springs in tube sockets should make firm contact with the tips of tubes; rheostats should be so made that fine control of current is possible. We have had the best results with carbon-compression rheostats. All the parts used should be mechanically well-made. We have seen poor insulation melt before a soldered connection could be completed; condenser plates short-circuit; and friction contact points fail, or give rise to such high resistance that satisfactory results were impossible. Old parts, which do not meet the above standards, should, therefore, not be used.

For the convenience of the beginner we have shown a full set of parts for the two-tube receiver in figure 30. One may expect to pay about 25 to 40 dollars for standard parts such as are shown in this illustration. While a factory made receiver

may be purchased for this sum it is important to remember that batteries, tubes, and telephones are not usually included in the price of factory made receivers. A bill of materials, with comments, is given below for the purchase of all necessary items. We list the manufacturers' names for products that have given us good service. The reader should note that we have not included the aerial and ground fixtures.

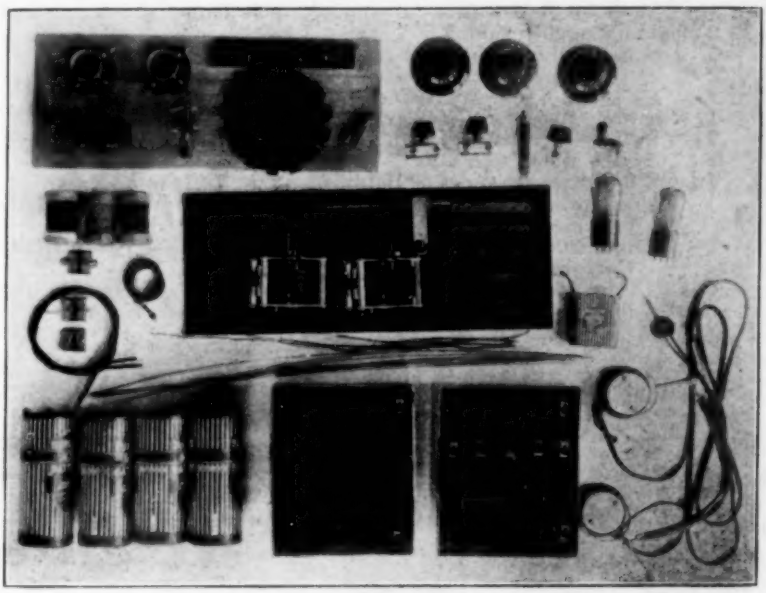

FIG. 30. PARTS THAT YOU WILL NEED FOR THE ROBERTS' TWO-TUBE RECEIVER.

XI. WHAT YOU NEED TO BUY.

Quantity	*Item*	*Cost*
4	Angle irons, brass, one-half inch by one and one-half inch	
1	Battery, C. 4½ volts (Eveready or Burgess)	
2	Battery, 45 volts, variable (Eveready or Burgess)	
4	Battery, 1½ volts, dry cell (Burgess)	
6	Binding posts, with screws	
10 lengths.	Bus bar, round	
3	Condensers, fixed 1—.005 mfd. 1—.0025 mfd. 1—.00025 mfd. with grid leak clips (Dublier micadon)	
2	Condensers, variable, .0005 mfd. (Cardwell, Hammarlund, or General Radio)	
24	Contact points, with nuts	
3	Dials, diameter 3 inches (Kurz-Kash)	
1	Fahnestock clips, 2 inches, No. 9	
1	Grid leak, 3 megohms, or to suit tube used (Daven)	
1	Jack, single circuit (Carter)	
1	Panel, rubber, size 7 by 18 inches (Radion)	
1	Plug (Weston)	

2 Rheostats (Bradleystat, latest model)
2 Rubber strips, for binding posts and neutrodon, ¾ inch by 7 inches
30 Screws
2—machine, 6–32 inch, with nuts and washers
12—one inch, brass, round head no. 7
12—one-half inch, brass, round head no. 6
4—only, one inch, round head brass no. 7
3 ft. Solder, resin core
2 Sockets, standard for 201-A tubes, or for UV-199 tubes (General Radio or similar make)
1 Shaft for tickler, brass or wood ¼ inch diameter, 5 inches long
2 lengths Spaghetti tubing
5 Spiderweb forms (buy or make)
2 Strips, brass or rubber, size ¾ inch by 5 inches
1 Sub-base, wood, size ½ inch by 8 inches by 18 inches
1 Switch, A-battery (Yaxley)
2 Switch-lever arm 1¼ inch
2 Switch stops, with nuts
1 pr. Telephones (Brandes or Baldwin)
1 Transformer, audio frequency, ratio 5 to 1 (General Radio or Amertran)
2 Tubes, 201-A for storage battery or UV-199 for dry cells (Radio Corporation or other standard make)
2 in. Tubing, ¼ inch, copper or brass
5 in. Tubing, glass, to fit inside copper or brass tubing
½ lb. Wire, no. 22 D. C. C. white
¼ lb. Wire, no. 26 D. C. C. white
¼ lb. Wire, no. 26 D. C. C. green
1 ft. Wire, flexible insulated, number 18 or 20
2 Washers, ¼ inch, copper, brass, or fibre

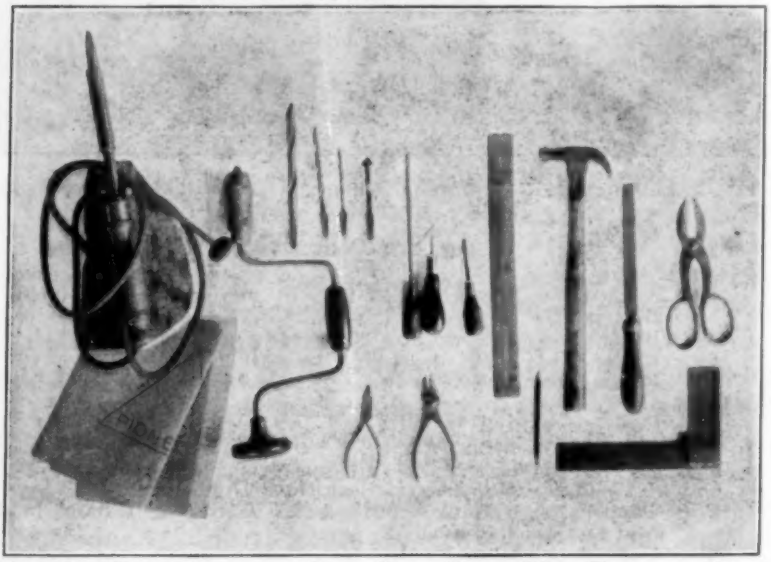

FIG. 31. RADIO RECEIVERS HAVE BEEN BUILT WITH THREE OR FOUR TOOLS, BUT WE HAVE FOUND ALL OF THESE TOOLS USEFUL.

XII. PRELIMINARY CONSTRUCTION.

Figure 31 shows the necessary tools and also some that will be found useful. We have found the long screw driver most

convenient. It has been found also that most of the drilling in radio construction can be done with drills of three different izes, viz., numbers 17 and 27, and 9-16 inch.

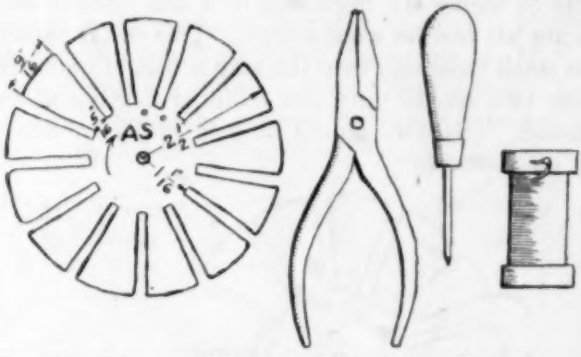

FIG. 32. WHAT YOU NEED TO WIND THE FIRST COIL. PUNCH TWO HOLES NEAR THE CENTER TO HOLD THE END OF THE WIRE.

FIG. 33. WINDING A SPIDER-WEB COIL FOR THE ROBERTS' RECEIVER. BE SURE TO CHECK THE NUMBER OF TURNS AND DIRECTION OF WINDING AFTER EACH COIL IS FINISHED.

It is best to construct all of the smaller devices previous to the assembly of the essential parts on the baseboard and panel.

Figure 32 shows a fibre form ready to wind. The two small holes near the center can be made with an awl or small nail. These holes should be made smooth with a sharp knife or safety razor blade. The arrow on the coil shows the direction in which the coil should be wound. *Be sure to mark all coils with arrows and letters.* If home-made coils are used the edges of the spokes should be smoothed with sandpaper to prevent injury to the insulation on the wire.

In figure 33, the reader will see a high school boy winding a spider-web coil. The spool from which he winds is in a drawer of the desk to keep it from unwinding too fast.

Figure 34 shows the beginning of a coil. About eight inches of wire are left free for a connection. This end is passed through the two small holes and then the wire is wound under two spokes and over two spokes until the required number of turns have been made. The wire should be held firmly so that it will lie evenly on the form.

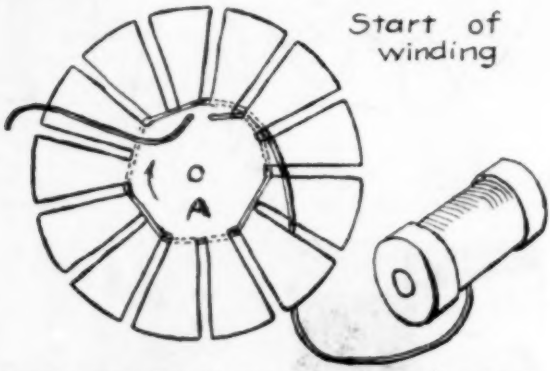

FIG. 34. THREAD THE END OF THE WIRE THROUGH THE TWO SMALL HOLES AND WIND OVER TWO SPOKES AND UNDER TWO SPOKES IN THE DIRECTION OF THE ARROW.

As soon as one or two turns have been made the eight-inch end may be coiled around a lead pencil and the wire kept out of the way as the winding proceeds.

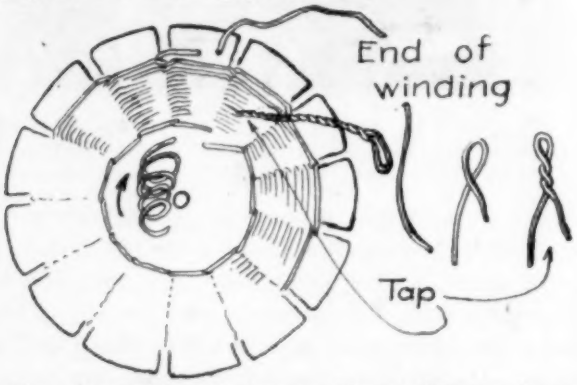

FIG. 35. KEEP LOOSE ENDS OUT OF THE WAY BY MAKING COILS AROUND A PENCIL. MAKE TAPS AS SHOWN.

A coil of this type is shown in figure 35. After the last turn has been made punch two small holes in the fibre and fasten

the outside wire as shown in figure 35. Keep about eight inches of wire at the outside end for a connection.

In assembling the parts the coils must be placed so that the turns will be in the same direction, and the beginning and end of wires located in the positions shown in figure 36. If the coils are all wound clock-wise, as shown in figure 36, these ends should be in the position shown. Notice that in coil A one end of the wire can be seen, the other end and the taps are on the opposite side. In coil S both ends are on the back side.

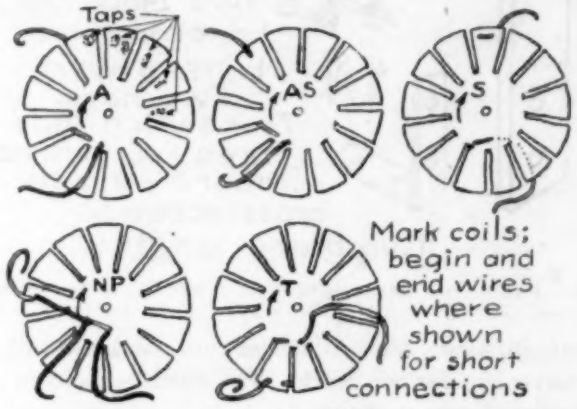

FIG. 36. ALL SPIDER-WEB FORMS SHOULD BE MARKED WITH ARROWS AND INITIAL LETTERS BEFORE THE WINDING BEGINS.

The coils should be wound in the following manner:

Coil A. No. 22, double cotton-covered wire, wind over two, under two, forty turns, tapped as follows: wind one turn and make a tap; wind another turn and make a tap; then make taps at the end of the fifth, tenth, twentieth, and thirtieth turns. The fortieth turn will be the end of the winding. A tap is made by folding six inches of wire back on itself, then twisting the wire so as to form a loop. This is shown in figure 35.

Coil S. No. 22, double cotton-covered wire, wound over two, under two, for forty turns; no taps are made.

Coil AS. Wind exactly the same as coil S, but the ends are on the other side of the form as shown in figure 36.

Coil T. No. 22, double cotton-covered wire, wind over one, under one, eighteen turns; no taps.

Coil NP. The NP coil may be wound with a single wire, No. 26. Forty turns are made and a tap made at turn 20. This tap is the soldered connection mentioned in the instructions. It should therefore go to the wire leading to the jack. The other two terminals are connected as described.

A support for the spider-web coils is illustrated in figure 37. If rubber is used it should be laid flat against a board when sawed

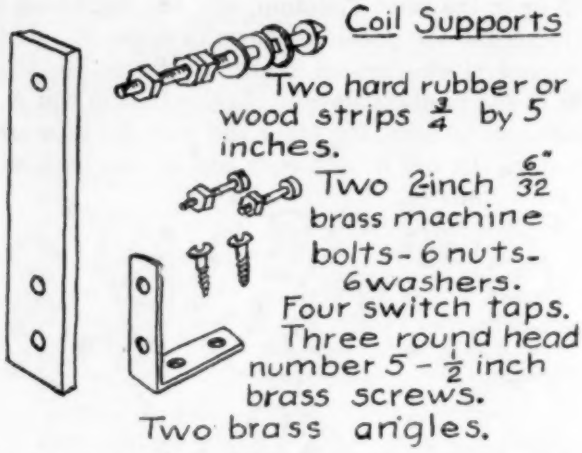
Coil Supports
Two hard rubber or wood strips ¾ by 5 inches.
Two 2inch 6/32 brass machine bolts-6 nuts-6washers.
Four switch taps.
Three round head number 5 - ½ inch brass screws.
Two brass angles.

FIG. 37. PARTS FOR COIL SUPPORT. TWO SUCH SUPPORTS SHOULD BE MADE.

as shown in figure 39. A hacksaw or backsaw will be found most convenient for this work. The mounted coils in a finished receiver are shown in figure 51.

The tickler coil is used to vary the intensity of the signals or music by changing the position of the coil with reference to another coil. In figure 51, the coil at the extreme left is the tickler coil. In figure 38, the parts used in the mounting for this coil are shown.

The panel bushing and collar are taken from a switch lever. Any washers of suitable size will do. They may be made of copper, brass, or fibre. Do not use iron.

A Fahnestock clip No. 9 placed between the collar and the panel provides the necessary friction properly combined with freedom of motion. The hole in this clip will have to be bored larger to take a shaft one-fourth inch in diameter. If a brass shaft is used one end should be hammered flat before the holes are bored for the switch taps that hold the coil.

After the spider-web form has been bolted to the shaft the parts are assembled as follows: Push the collar on the shaft and after it a large washer; then slide on the Fahnestock clip with the free ends against the washer. The end of the shaft is now pushed through the bushing in the panel and another washer is slipped on. Next the dial is put on and its set-screw tightened.

The necessary friction on the tickler shaft is obtained by pressing the dial against the bushing and forcing the collar against the Fahnestock spring while the dial is held in position. The collar should be fastened in such a position as to permit easy movement of the shaft by the dial.

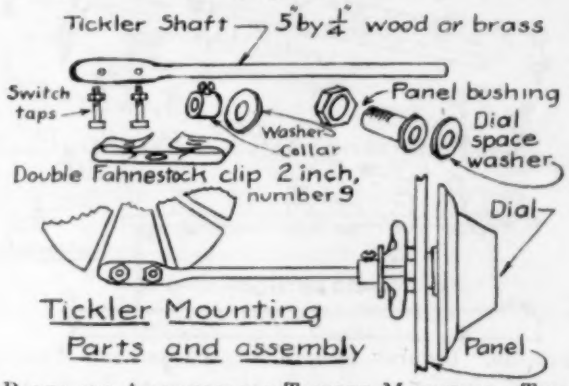

FIG. 38. PARTS AND ASSEMBLY FOR TICKLER MOUNTING. THE DOUBLE FAHNESTOCK CLIP GIVES FINE ADJUSTMENT OF THE TICKLER.

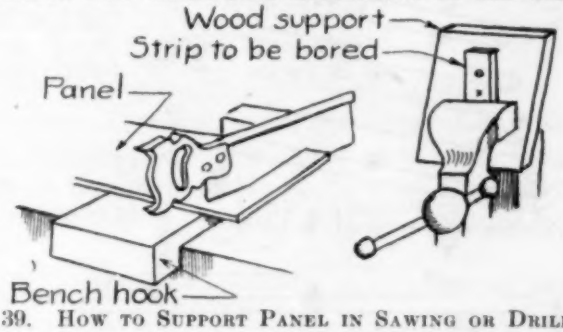

FIG. 39. HOW TO SUPPORT PANEL IN SAWING OR DRILLING.

If a wooden rod is used for the tickler shaft the fibre form must first be fastened to a piece of wood about one-half inch square and two inches long. (See Fig. 30, on panel.) A hole for the shaft is bored through one end of this strip. The fibre form is mounted to it by means of a screw in the center of the form. This wooden mounting is shown in figure 30.

The construction of the binding-post strip is shown in figure 40. The holes for the binding post screws should be one inch apart, and the holes for the switch tap screws, one-half inch from the ends. In putting these parts together, fasten the angle supports to the rubber strip first. The switch taps may be too long. If so, they can be cut off by filing half through the screw and then bending the end with pliers. Always have the nut on

the screw before cutting off an end so that there will be no trouble in replacing the nut. Taking a nut off helps to smooth the rough edges left in filing. Next put in the binding posts. Those at the ends should not touch the brass angle supports.

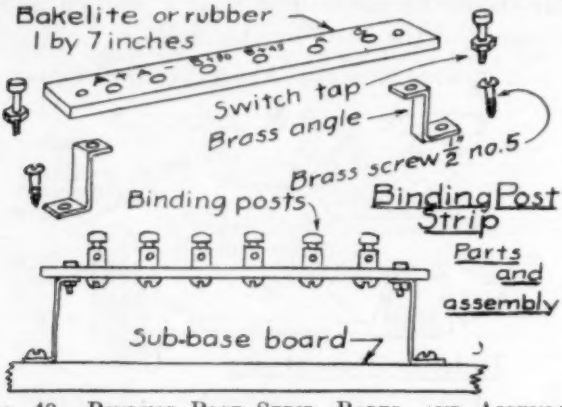

FIG. 40. BINDING POST STRIP, PARTS, AND ASSEMBLY.

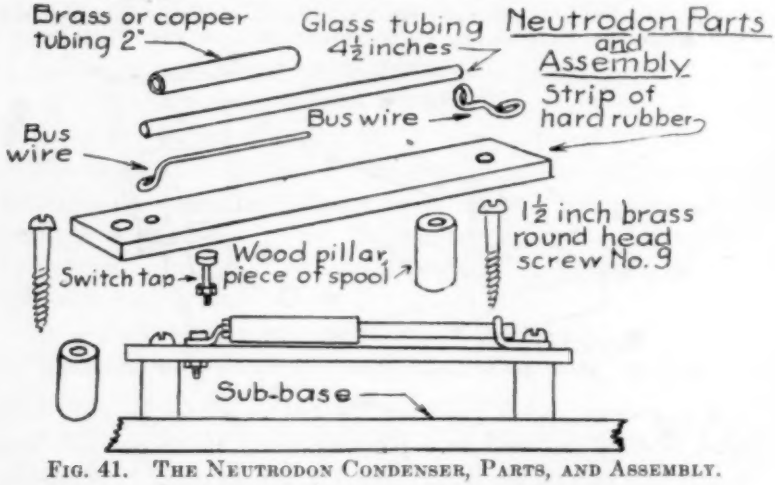

FIG. 41. THE NEUTRODON CONDENSER, PARTS, AND ASSEMBLY.

The neutrodon condenser is a small variable condenser made of a piece of metal tubing, an insulator, and a piece of copper wire. The parts and assembly of this condenser are shown in figure 41. If you can not obtain a piece of glass tubing use a piece of spaghetti or cambric insulation.

The switch used for the aerial coil may be mounted behind the panel between the variable condensers as shown in figure 51. Bend two pieces of bus wire or heavy wire as shown in figure 42. Take off the nuts from the switch stops. Slip one wire over

each and replace the nuts. The outer ends of these wires should be fastened to the back of the condensers by screws provided on the framework.

Fasten between backs of variable condensers by two pieces of bus wire from switch stops to convenient screws on variable condensers

FIG. 42. THE AERIAL SWITCH IS MOUNTED BETWEEN THE CONDENSERS BEHIND THE PANEL.

(To be continued.)

PUPIL OPINION OF BIOLOGY AFTER TWO MONTHS ATTENDANCE.

BY MARY ELIZABETH PAPE,

Marietta Senior High School, Marietta, Ohio.

The questionnaire as a means of obtaining information is not always the most reliable method but it often brings some interesting returns. In four sections or classes of beginning biology given in the tenth year of high school the following questions were asked:

1. About how much time do you spend on each lesson in biology?
2. Do you like the subject biology? Why?
3. Which do you like better, recitation or laboratory work? Why?
4. Does the study of biology stimulate into thinking about things surrounding you that you had not thought of before?
5. What do you consider as the most disagreeable thing you do in connection with this course?

It was explained that they had no influence whatsoever on their grades. Out of more than one hundred pupils taking the subject, about seventy-five per cent answered most of them. It was purely voluntary on the part of the pupils. Most of the pupils had had general science last year with only a few teacher demonstrations. They have this year (since September) had their first individual laboratory work with only a few teacher demonstrations. Therefore, laboratory work has been a new method of instruction to them. The following tables give the results of the questions:

RESULT OF QUESTION 1.

Number of pupils	Time spent
1	10 minutes
7	15 minutes
6	20 minutes
5	25 minutes
17	30 minutes
3	35 minutes
2	40 minutes
6	45 minutes
1	50 minutes
15	1 hour
1	2 hours
3	"Varies"
1	"As much as I can"
1	"Don't know"
6	Did not answer

RESULT OF QUESTION 2.

Number of pupils	Reply
66	"Yes"
9	"No"
1	Did not answer
Number of pupils	**Reason**
47	Biology interesting
4	Disliked it because of laboratory work
2	Biology uninteresting
2	Not interested in biology
1	Disliked it because of dislike to specimens
1	Disliked it because "too many new terms"
14	Did not answer

RESULT OF QUESTION 3.

Number of pupils	Reply
63	Like laboratory better
8	Like recitation better
4	Like both equally well
1	Did not answer
Number of pupils	**Reasons for preferring recitation**
4	"Clarifies ideas"
3	"It brings out the subject more plainly"
2	"Don't like to draw"
1	"Less time required to prepare recitation"
Number of pupils	**Reasons for preferring laboratory**
21	"Like to see things for myself"
12	"Interested in laboratory work"
9	"Interested in laboratory technique"
7	"Get to see the proof of things"
4	"Interested in drawing"
3	"Laboratory not so tedious"
2	"Trains one to do things for himself"
1	"Not so many scientific names in laboratory"
1	"Laboratory work explains the recitation"
1	"Time in laboratory passes quicker"
1	"Have a good teacher"
3	Did not answer

RESULT OF QUESTION 4.

Number of pupils	Reply
66	"Yes"
2	"No"

2	"Sometimes"
1	"Not altogether"
2	Did not answer

RESULT OF QUESTION 5.

Number of pupils	
12	"Writing laboratory notes"
9	"Nothing"
9	"Tests"
4	"Notebook"
3	"Dissecting animals"
3	"Drawings"
2	"Dislike to study"
2	"Laboratory work disagreeable"
1	"Let my notebook slip"
1	"Recitation not interesting"
1	"Everything"
1	"Learning long definitions"
1	"Learning new scientific terms"
1	"Working with live specimens"
1	"Can't remember things"
1	"Trying to get a good grade when I know it impossible"
23	Did not answer

Assuming that most of the answers were truthfully given, one might judge from the tabulations that most of the pupils liked the subject and preferred laboratory work to recitation.

It is interesting to note from these results the attitude of pupils toward laboratory work in relation to the opinions of teachers of biology toward individual laboratory work as revealed in an investigation conducted by the writer last year. That survey aimed to ascertain, among other things, the teacher's evaluation of laboratory methods. With replies from schools representing all sizes and types, the conclusion showed the individual pupil method in slight predominance over teacher demonstration method. The individual method by the pupil ought to do much toward bringing out latent talent and ability and discouraging disqualified ambitions that are quite prevalent among some pupils of high school age. This school is unusually well equipped with materials and apparatus for individual laboratory work—that may be the reason for many preferring it.

INCREASED STIPEND FOR RHODES SCHOLARS.

Rhodes scholars from the United States and Canada during the past 20 years, according to a statement of the American secretary of the Rhodes Trust, have made almost identical academic records at Oxford University. Among the 420 candidates for appointment considered at the last election of scholars to enter the university in October, 1926, Ohio led with 39 candidates, and Pennsylvania had 30. The stipend has been increased recently, and the 32 men elected will have an annual income of £400 each for the three years of their residence at Oxford.

CHEMICAL NOTES ON PORTLAND CEMENT MANUFACTURE.[1]

By D. I. Elder,

Universal Portland Cement Co., 210 So. La Salle St., Chicago.

PART I.

The American Society for Testing Materials has given perhaps the most comprehensive definition of Portland cement, which is:

"The product obtained by finely pulverizing clinker produced by calcining to incipient fusion an intimate and properly proportioned mixture of argillaceous and calcareous materials, with no addition subsequent to calcination except water and calcined or uncalcined gypsum."

The standard specification further provides that "the following limits shall not be exceeded:"

	Per Cent
Loss on ignition	4.00
Insoluble residue	0.85
Sulphuric anhydride, SO_3	2.00
Magnesia Mgo.	5.00

In other words, cement is a highly artificial product made by combining substances that contain silica, alumina, and ferric oxide with those that contain calcium oxide. Further, the materials must be as free from magnesium oxide as possible, and under the high temperature at which the resulting mixture forms clinker chemical combination is so complete that the silicates are rendered soluble in dilute hydrochloric acid. The addition of gypsum is for the purpose of controlling setting and hardening properties, and the percentage of sulphuric anhydride definitely limits that addition. The loss on ignition includes the water of crystallization derived from the added gypsum with whatever moisture and carbon dioxide may be absorbed from the air during the process of grinding the clinker and storing the cement.

Manufacture of Portland cement is perhaps one of the best examples in modern industry of the production on an enormous scale of a useful commodity whose properties depend on exact control of substances that react chemically during the process.

In general, and taking the average of commercial brands from all over the country, the composition of the clinker before it is ground will fall within certain fairly well defined limits about as follows:

[1]Read before the Chemistry section of the C. O. S. and M. T. at the University of Chicago, November, 1925.

	Per Cent
Silica	19 to 22
Alumina	5 to 7
Ferric oxide	1.5 to 3
Calcium oxide	64.5 to 66
Magnesium oxide	1.5 to 5

The total of these constituents in well proportioned and thoroughly burned clinker will be about 98 per cent to 98.5 per cent, the balance consisting of manganese oxides, alkalies, a trace of sulphate and any other non-volatile materials that may exist in minute quantities in the raw materials.

In well proportioned mixtures a certain relation exists between the silica on the one hand and the alumina plus ferric oxide on the other hand, which may be expressed by saying that if the percentages of alumina and ferric oxide are added, and the percentage of silica divided by this sum, the quotient should be between 2.25 and 2.5; or perhaps more simply, the percentage of silica should be from two and one-quarter to two and one-half times the combined alumina and ferric oxide.

Now it may be, and probably is true that some of the standard brands of cement slightly exceed these limits, and it is readily admitted that the rule for composition is not a hard and fast one, but one that has merely been developed by years of practical experience. At the same time much is left to ingenuity in using the materials that are available for cement making and if it is possible in any given case to make an acceptable product whose composition lies outside the limits given above, there is no restriction against it.

What are the raw materials available for use? Since a fairly definite chemical composition is the aim, any combination of materials that will give that composition is permitted, and the question of practicality should govern the choice. It was early found that for the argillaceous constituent the silica should exist in the state of combination, and that sand could hardly be used on account of difficulty in meeting one of the first principles, namely that of an intimate mixture. So in practical use today we find combinations of pure clay and pure limestone; also of clay or shale in combination with fresh water marl, which is a calcium carbonate mud found in lakes in the glacial sections of Michigan and elsewhere. Also in extensive use are certain limestones and shales that contain so high a proportion of calcium carbonate mixed with silica and alumina that the requirements for proper proportions are almost met, careful selection only being required to make a correct mixture.

Finally enormous tonnages of cement are produced in which the argillaceous constituent is blast furnace slag, which contains the requisite elements in a state of combination, the addition of more calcium oxide only being required to make a highly satisfactory mixture.

Briefly describing the manufacturing process, a modern plant of only ordinary capacity will consume a thousand tons of limestone in a day; and the larger plants may consume materials at the rate of several thousand tons daily. In treating such large quantities of material only machinery of the largest size yet devised is employed in modern practice and the factor of human labor reduced to a minimum. The man with shovel and wheelbarrows is no longer much of a factor.

Natural materials that have to be taken from the earth, such as limestone, are blasted out—often two carloads of high explosive being fired in a single shot—displacing sometimes as much as a hundred and fifty thousand tons of rock. Steam shovels load it aboard cars which transport it to crushers where it is reduced to one inch size.

At this stage American practice follows one of two procedures: either the materials are dried till they contain less than one-half of one percent of moisture, then weighed out in prescribed quantities, mixed and ground; or else they are proportioned by weight, mixed and ground in water suspension. The two processes are known respectively as the dry and the wet. In the former case the raw material emerges as a dry powder so fine that 85 per cent or 90 per cent will pass a 200 mesh sieve, having 40,000 openings per square inch. In the latter or wet process the material, ground equally fine, is in the form of a thin mud that can be pumped. This operation of mixing and grinding satisfies the provision for an intimate and properly proportioned mixture.

PART II.

The process of calcining to incipient fusion, known as burning, deserves more than mere passing mention. Portland cement had its origin in the lime industry, and for years a modification of the lime kiln was used for burning, dried raw material briquettes being charged at the top with fuel, and clinker being withdrawn at the bottom, the middle portion being the burning zone and at a very high temperature. In order to effect combination the materials must approach the fusion temperature, at which they become soft and sticky. So in operation,

the old style shaft kilns were subject to certain difficulties. The clinker formed large masses inside it which required much labor to jar loose and which interfered with draft and the even descent of the furnace burden. The large clinker masses when drawn out and sledged up were found to have a crust of well-burned material and a core of under-burned material in which proper combination of the elements had not taken place. Hand sorting was necessary and the labor was excessive.

The rotary kiln, invented in the United States, consists of a steel shell lying on its side, with its long axis inclined at a pitch of three-eighths of an inch to the foot. In length kilns vary from one hundred feet to two hundred feet and in diameter from seven feet to twelve, modern tendency being to large units. The shell is lined with a special refractory block that is accurately shaped to fit the circle of the shell. The rear or higher end is housed in a flue to carry off the waste gases, and the front or lower end is housed in a firebrick chamber. Some distance from each end the shell is encircled by a tire that rests on rollers and its middle is encircled by a gear ring that meshes with the driving mechanism. The kiln turns on its long axis at the rate of about once a minute.

Powdered coal is blown into the kiln at the lower or front end through a pipe that pierces the housing, where it burns like a gas flame. Raw material—dry powder in the dry process and liquid mud known as slurry in the wet—is fed in at the rear or upper end. With each turn of the kiln it slides forward a little and gradually travels toward the heat. In the course of its travel it gives up first its moisture, its combined water, its carbon dioxide and finally about thirty feet from the front end, under the flame it reaches the "burning" temperature, a glistening white heat, about 1450 degrees C. As the kiln revolves the load of raw material is carried up the ascending quadrant, rolls over and breaks up, exposing fresh surfaces to the heat, so that all is burned uniformly and finally drops out the end in the form of pellets the size of marbles. It is conveyed away and spread in piles to cool.

The enormous expansion of the cement manufacturing industry dates from the invention of the rotary kiln and the use of powdered coal for fuel. It is true that natural gas and crude oil are each used where they are available, but powdered coal is the most accessible in most localities. Hand sorting of the clinker has been entirely eliminated, since the clinker is all of

uniform character and of standard grade throughout. One man can operate two large kilns and intelligence takes the place of hard labor.

If now the clinker were powdered up alone it would be found that when mixed with water it would set very quickly, perhaps in fifteen minutes. But for practical use the rate of setting must be modified to allow time for the cement to be mixed with water and sand, placed within forms or on the highway grade, tamped into place and the surface finished. It should not set under an hour but should set hard in ten hours or less. It has been found that the addition of a small amount of gypsum, usually 3 per cent, accomplishes this modification and acts beneficially in accelerating the increase in strength of the concrete during the first several days after it is placed. Therefore, before grinding clinker the proper amount of gypsum is weighed out with it, the whole ground together and the finished cement conveyed to the warehouse.

Chemical control is exercised throughout the process, from the natural deposits of raw material till the product is delivered aboard cars or ship; and the laboratories for chemical and physical testing are usually very completely equipped. Routine analytical work comprises complete and exact analyses of all materials represented in the various steps of manufacture, average samples being collected and assembled daily. The information derived is of value in a variety of ways. In addition quick determinations of loss on ignition and of calcium oxide are required at frequent periods—perhaps hourly—since these figures are used as indices of composition in the case of any particular set of raw materials.

For years one great puzzle was: what is the state of combination of the lime in Portland cement clinker. And in the process of setting after being ground to cement and mixed with water, what is the change that causes it to harden. If clinker was broken with a hammer it revealed a vitreous structure and its constitution was baffling. Various men did brilliant work on this problem in earlier years and found that by preparing mixtures of pure silica with pure lime a silicate was produced that contained one molecule of silica in combination with one molecule of lime; also a stable mixture containing three molecules of lime with one of silica. But the product of preparing a mixture of one molecule of silica with two molecules of lime appeared to be unstable, for when it cooled after clinkering it fell to

powder. Likewise a mono-calcium aluminate was prepared. Therefore it was concluded that clinker contained the tri-calcium silicate and the mono-calcium aluminate and tentative formulae based on this assumption were in use for a long time for estimating the lime necessary to make clinker, if the relationship of silica alumina and ferric oxide were known in a given set of materials. Later the problem was attacked by the methods of petrography and much light has been shed on the constitution of clinker by research done at the Bureau of Standards.

If minerals are ground to thin section, mounted on the microscope stage and illuminated with polarized light, they have a characteristic appearance when viewed through the microscope. And this method was applied to clinker sections. By preparing mixtures of pure materials a whole series of silicates and aluminates was produced which exhibited characteristic crystalline form by polarized light in the microscopic field and then various of these crystals identified in sections of clinker. So now it appears as if clinker consists of varying amounts of the di-calcium and the tri-calcium silicates, mixed with the tri-calcium aluminate and a compound containing five molecules of lime in combination with three of alumina. The function of ferric oxide is as yet not clear, for although it may combine with lime, it often appears merely as the oxide.

Now on grinding the clinker to cement and mixing with water, hydrolysis takes place, splitting off calcium hydroxide and mono-calcium silicate and for a long time the act of setting was explained on the basis of interlacing crystals. Later, however, a colloid theory of setting came into favor, according to which gelatinous particles solidified from water suspension. It may be there is basis for both suppositions and there the explanation seems to rest for the moment, awaiting continued research.

At any rate, when cement is mixed with the proper aggregates it becomes extremely hard and durable. Formed into briquettes in the proportion of one part cement with three parts of standard sand, it attains a tensile strength of 200 pounds in seven days and 300 pounds in a month. Usually the commercial brands exceed this minimum by a substantial margin. Properly mixed concrete at six months will not be crushed under a load of a ton to the square inch and may stand much heavier loading. Demand continues to increase and is rapidly giving our civilization a concrete setting.

THE RECITATION IN MATHEMATICS.

By Charles A. Stone,
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In presenting my discussion on the above topic it is appropriate to quote a young teacher who had obtained a position in a progressive school system. Her statement is as follows:

"As a very small tot, regarding with awe the factotum behind the teacher's desk, I reached a conclusion as to the function of the recitation. Why did we recite? So the teacher could find out what we did not know, of course.

"This idea of the recitation I cherished through a period of normal training and a year of substituting. It was not until I sat really on the other side of the fence, and looked over at a class of my own, for whom I was fully responsible, that I made the saddening discovery; in order to recite a class must first know. I felt somehow cheated of what I had conceived as the main pleasure of teaching: catching the pupil and getting him without the goods; puzzling him so that he would respect my superior knowledge.

"I seemed to be in the position of the old lady who, having faced a strong and bitter wind all the way to church, prayed the wind might change before her homeward journey. Her prayer was answered so that she faced the veered wind all the way home. Similarly I, who had struggled all the years of my school life to keep one jump ahead of the teacher's question, when conditions were reversed found myself facing only new difficulties. I must see that the pupils knew something, rather than flaunt the fact that they didn't."

It is surprising to see how many teachers share this early conception of the recitation. Many now agree that the average recitation is a place where facts are poured into the mind of the child later to be regurgitated only half digested through the commonly used extractor, the examination. Such recitations evidently do not serve the only real function of a recitation which is to provide a means of expressing, acquiring, or distributing knowledge. The recitation is just one step in the teaching process.

Patently the recitation is not the first step in this process. A child cannot express knowledge that he does not possess; he cannot distribute to others what he hasn't himself; he cannot even ask many intelligent questions so as to acquire knowledge through the recitation until he has a mental grasp of the

subject, knows its scope, and sees its relation to himself. Therefore something must precede the recitation.

The preceding step may be a lecture by the teacher. In that case very little thinking is required of the pupil. He does not need to reason out phases nor applications of the subject. For him the recitation resolves itself into a memory test, an oral examination.

On the other hand preparation for the recitation may devolve on the student himself in the form of required study. The study may be random; on his own time and under self chosen or unconsidered conditions. Or the study may be supervised; under the direct control of the teacher. The advantages of the last method seem unquestionable. Through supervision the physical conditions of study so important for efficiency may be regulated; individual effort may be insisted upon; the bright pupil may be encouraged; the laggard may be spurred on; the struggling pupil may be aided; the progress of the class as a whole and of each member of it may be observed. In other words the evils of mass instruction may be obviated and the benefits of individual instruction afforded in some degree to the student.

Before the data acquired through study is available for recitation purposes it must be organized by the student. Unless the pupil's knowledge consists in definite ideas bearing a definite relation to each other it is of little value to him for recitation or later application. The student should have a mental framework on which to hang his facts so that they are not isolated but are important in relation to some big broad idea which he realizes has a bearing on his own life and experience.

Especially important is this organization as a preparation for the mathematics recitation. "The primary aim in mathematics is to develop a mode of thought—an ability to analyze and see relationships and to determine them." Therefore the placing of little bits of new mathematical information in relation to the great general notion of mathematics which the child is forming is essential to teaching the subject. And this placing, the organization of knowledge by the pupil direct is a great aid.

When the preparation is complete the mode of the class period itself presents many possibilities. We have first the classic recitation period. Here the lecturer breathes forth words of wisdom supposedly subject to question and discussion by the class. In some of the junior and senior classes of high school this form of conducting class work still prevails. The

teacher promulgates the articles of mathematical dogma in time honored order and in traditional terms. Here the teacher is the main cog in the machine with the pupil in a state of passivity. The pupil merely digests and we all know what happens in the physical order when too much digestion takes place without a corresponding exercise of the other parts of the body to justify the consumption of food. Similarly continued assimilation of mental pabulum without working it off by solving life's problems will result in state of mental lethargy until the student will refuse to even exert himself enough for digestion.

A type of recitation is the time honored question and answer method which has degenerated to a mere test of memory. By its use, as in the lecture method, the recitation is in danger of being very one sided with the teacher holding down the heavy end. Initiative on part of student is lacking here, as he does not think independently in this procedure but is led on to think as the teacher wants him to think.

James has suggested an improvement on the above method by extending the privilege of questioning to the pupil, and would permit the pupil to be a leader in the discussion. This he calls the "philosopher's laboratory." Here mind meets mind on the same plane to dissect, analyze and classify thoughts and values. In this way real interest is aroused, real questions are brought up, and there is a stimulus for increasing knowledge. Under these conditions the mind is in its highest state of activity and receptivity, thus making for learning at its best.

With the aim of approaching this ideal condition as nearly as possible in a schoolroom, the so-called socialized form of recitation has been devised. This recitation implies freedom of speech on the part of all members of the class subject of course to restrictions of order and good manners. It aims also at maximum activity of the class, everybody actually doing something whenever possible. This is highly desirable for in activity is growth.

The activity may be mental. Any teacher will admit that an ideal class is one in which every one is thinking. The fact that an opportunity for expressing an opinion is provided in the socialized recitation makes the student wonder if he has an opinion—the hearing of the opinions of others in exactly his own position impels him to form one too—and the favorable informal atmosphere of the lesson encourages him to express it.

He is flattered by the attention of the others, new ideas spring up full grown in his mind in response to their questions and objections and his mind expands in a warm glow of activity.

The brighter student has every chance to display initiative. And who will deny the importance of initiative in these days of education of the masses when everybody knows the ordinary things and only the man with the new idea is noticeable? The dullest student is moved to question about this matter over which they all seem so excited and even he enters the discussion. Such are the claims of the sponsors for the socialized recitations. It all sounds very idealistic, but how can it be carried out in mathematics? The technique varies with different teachers and for different purposes:

At the University High School the subject matter is divided into units. Each unit is complete in itself and contains all material that can be taught together. The technique of presenting a unit of work to a class is as follows:

(1) The teacher endeavors to find out what the pupil's previous knowledge of a unit is. This serves as a basis for motivation as it is often possible to connect the material in the unit with real life experiences of the pupil.

(2) The teacher now presents a brief, expository survey of the unit, leading the pupil rapidly over the road he is to travel, giving him a bird's eye view of the same.

(3) The pupil now works out the details for himself during a period of supervised study.

(4) After the pupil has gone through the entire unit and has gathered the necessary information regarding the unit, he organizes the material obtained as an author would if he were preparing a book in outline form. This is done to enable the pupil to get a clear conception of the unit and the relation of each part to the whole.

(5) After going through the above steps the pupil is really ready for a recitation. He has gone through the unit, gained knowledge and has organized it. He thus has something to recite. At the beginning of the recitation period cards are passed out at random to the members of the class. On these cards are written the topics for discussion. After five minutes pupils are called on to discuss their topic and step up to the front of the room where they make their talks. A talk may take five minutes to thirty minutes or longer depending upon the extent of the topic discussed. In presenting his topic the pupil actually teaches the

class as the teacher would were he discussing the same. During a recitation the pupil is not interrupted by the teacher or any of the other pupils. At the close of the recitation the pupils or teacher may question and criticize. Thus the recitation is a class procedure with only the pupils participating and the teacher acting as a spectator, but ready to step in and settle any disagreement that might arise. No teaching is attempted at this time. If teaching is needed the recitation should not have been attempted.

Some of the advantages derived from the above type of recitation are as follows:

1. Trains in oral expression.
2. Gives a social motive to the work of the pupils.
3. Trains in leadership and in initiative.
4. Trains in courtesy and consideration.
5. Lends a play-interest to learning.
6. Increases self reliance in the child.
7. Increases keenness in the judgment of the child through evaluating opinions and methods of others and in receiving criticism of his own work.

SCIENTIFIC PSYCHOLOGICAL PRINCIPLES APPLIED TO A TYPICAL TEACHING SITUATION IN FIRST YEAR ALGEBRA.

By Orlie M. Clem,

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Too frequently psychology is "taught" and "learned" abstractly. The best evidence of this is the familiar phrase, "The plan seems good in theory but it won't work in practice." Such a conception has little place in modern educational thinking where an outgrown metaphysics has given place to a functional psychology. From the functional point of view there is no conflict, no divorce, no discrepancy between theory and practice. What is good in theory does work in practice, and conversely.

The writer is engaged in the training of secondary school teachers. He is a thorough believer in professional courses in education, and yet he is sometimes shocked in observing teachers in training and in the field after graduation. No one would recognize in the procedure of some that they had just finished courses in principles of education, philosophy of education, educational psychology, secondary education, etc. One would sometimes consequently suspect that these courses were like the measles or the whooping cough,—to be had and forgotten.

The professional training of any teacher naturally divides

itself into two fields which should go on at the same time and correlatively: First, the learning of principles; second, learning how to do the specific thing. Normal schools generally have tended to over-emphasize the latter, with the result that the teacher's training has been too stereotyped. Universities have tended to over-emphasize the former, with the presumption that the teacher knowing the principle will automatically make the right application in a concrete situation. Experience and observation prove this to be a dangerous fallacy. As Gates has emphasized, "We learn the reaction that we make."

Scientific experiment has made the field of education in recent years a veritable "Kimberley" or "El Dorado." Facts, principles, and laws of proved merit, treasure vats of educational worth, have been unearthed by the scientific investigators. But the question comes to us with full force, "To what extent is the actual teaching of the great army of lay teachers being affected?" There are two grave considerations to the promising picture above. The first is that far too few, the investigators chiefly, have viewed these treasures of the mind. The second grave consideration is that these treasures have been found but are still in the ore. They need to be made the coin of the realm, the legal tender of educational technique.

Edison, after he had found a filament which would burn for the electric light, worked a long time to make his product commerciable so that all might have it. An outstanding need in the field of education just now is the sorting out, the interpretation, and the practical application of the implications from educational research. The writer submits the following procedure as suggestive for teaching scientifically to a class in first year algebra, "The Square of the Sum of Two Quantities." It shows the application of some of the contributions of modern psychology to a typical teaching situation.

The teacher says, "Today we are going to have a new process 'The Square of the Sum of Two Quantities.' Mary, what is the square of a?" Mary answers "a^2." The class has had this in previous work. Other pupils are asked for the square of b, d, f, k, etc. The teacher then places $(a+b)^2$ on the board and explains that when a and b are written in this manner it means that the square of their sum is to be found. The pupils will understand that the square of their sum is to be found by multiplying the sum by itself. So $a+b$ is placed on the board to be multiplied

$a+b$

by the long or regular arithmetic method. "As I proceed, will you work with me, William." $a \times a = ?$ William says a^2 and the teacher puts it down. $a \times b = ?$ Henry? Henry says ab. He has already had this process. The teacher asks, "Why is the sign of ab plus?" Some one replies that it is because a and b are both plus. The teacher puts down ab. She proceeds to multiply by b, asking a pupil as before, and putting down $ab+b^2$ in the proper position. The teacher then draws a line and says, "John, will you add." John secures the result $a^2+2ab+b^2$. The completed work is then as follows:

$$\begin{array}{l} a+b \\ a+b \\ \hline a^2+ab \\ \quad +ab+b^2 \\ \hline a^2+2ab+b^2 \end{array}$$

The teacher shows that the process of multiplying is the same as when, for example, 24 is multiplied by 24 in arithmetic. The teacher then places on the board $(c+d)^2$. The multiplication is done in the same manner as the above, various pupils being called for different parts. Then, she says, "I am going to see if Helen can do one alone. Helen, will you go to the board and take this one alone, $(c+d)^2$?" Helen probably does it correctly. If not, the teacher sees that she is assisted by individual members of the class.

Then, the teacher says, "Now, I want to ask you people a very important question, the most important one I shall ask you today. And I want you to think on it very hard before answering.

"When we square $(a+b)$ what is the result, Robert?"

He says, "$a^2+2ab+b^2$."

"When we square $(c+d)$, Ellen?"

She says, "$c^2+2cd+d^2$."

"When we square $(c+e)$, Dorothy?"

She says, "$c^2+2ce+e^2$."

"Now, here is the question, I wonder if anyone can see a short way to do this. When we square the sum of two quantities, the result is? Will you think carefully and when some one sees what he thinks is a short way, will he please raise his hand."

In a short time Genevieve, one of the brightest pupils, will say, "It is equal to the square of the first one, then two times the

first and second multiplied together, then the square of the last one." The teacher says, "Exactly so, Genevieve. Let us see if Genevieve is not correct. Again, what did you say, Genevieve?" Genevieve repeats her statement with the teacher and pupils checking one of the multiplications on the board to see if she is correct. The other two multiplications are then checked by her statement.

The teacher then says, "May we formulate a good clear statement of Genevieve's contribution?" Looking at one of the problems on the board, she, indicating each step says, "The square of the sum of two quantities is equal to the square of the first, plus twice the product of the first by the second, plus the square of the second." The teacher proceeds, "Who can give us that rule now?" Grover says he can. The teacher calls on him and he probably gives it correctly. If not, he is assisted by the class. The teacher then calls on three or four other members of the class. Then, she says, "Let us give the rule together." And they give it in concert. Then in rapid fire succession she gives problems to members of the class. For a time brief periods of giving the rule and solving problems are alternated. Then the teacher says, "Let us find the result when $(a-b)$ is squared." So, $(a-b)$ is squared by the long or arithmetic method. She then asks, "What is the difference in result between the square of $(a+b)$ and $(a-b)$?" Some one easily sees that the only difference is the sign of the middle term. "Very good, will some one now give the rule for the square of the difference of two quantities." Some pupil says, "The square of the difference of two quantities is equal to the square of the first, minus twice the product of the first by the second, plus the square of the second." The teacher then leads the class in giving it four or five times together. The teacher then spends some time drilling the class, mixing up indiscriminately:

1. Rule for square of the sum of two quantities.
2. Problems in the square of the sum of two quantities.
3. Rule for square of difference of two quantities.
4. Problems in the square of the difference of two quantities.

What are the psychological points of merit in the above procedure?

1. The pupils do the work. The teacher leads them by questions.

2. The pupils are attentive. Their powers are challenged. They have to be awake to what is coming next.

3. Pupils are led into deep water, but are never swamped at any point. Each step is made perfectly clear. Units of thought are adjusted to the mental stride of pupils.

4. The pupils, under the direction of the teacher work out the rule themselves. Hence, it is much easier to learn. Definitions should usually be worked out in this way.

5. When squaring by the long method, the comparison with the arithmetic method clarified the situation greatly. It was connecting the new with the old.

6. Some one may ask, "Why square by the long method at all? Does this not clutter up the new process?" There are two replies to this question:

A. The long method makes the rule clear. Otherwise, the rule would be as meaningless as sanskrit.

B. The function of the long method is to make the rule clear. Only three problems are used for this purpose. So, with only three problems by the long method and dozens of others by the short or inspectional method, the long method aborts through lack of exercise. The long method is hence only a psychological crutch to be used only in the frail or convalescing period of learning. It should be removed, and is, in the procedure, as soon as the individual can get along without it. It will be noted that only one problem is solved by the long method in the case of the square of the difference of two quantities.

7. There is an interpenetration of the deductive and inductive procedure,—that is, an indiscriminate mixture of problem solving and the giving of the rules.

8. There is extensive repetition and drill. This is demanded in this type of work.

9. The initiative and originality of the pupil are keenly exercised in mastering the new points as the teacher proceeds.

10. It will be noted that $(a+b)$ and $(a-b)$ are both presented on the same day. There is a very significant reason for this. Should $(a+b)$ be presented alone and much drill given, due to the law of exercise and the sub-law of primacy, pupils would have in their nervous system the idea that in the squaring process the middle term is plus. This reaction deeply ingrained in the nervous system would unconsciously do a world of mischief later.

A STUDY OF SCIENCE ARTICLES IN MAGAZINES.

By A. H. Searle and G. M. Ruch,[1]

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One of the outstanding principles set forth for secondary education by the committee on cardinal principles was the need for reorganization. Gruenberg, in an article (1) entitled "Unifying the Aims of High School Science Teaching" states this need for the field of science thus: "The hopes aroused fifty or sixty years ago by the contemplation of the great human advances to be obtained by the general teaching of science have not been realized; education has not fully promoted the spread or the purpose of science."

Curtis in a study (2) entitled "Some Values Derived from Extensive Reading in General Science," says, "A study of extensive reading materials should be made in order to determine, where in books, pamphlets, magazines, etc., the needed information not supplied in the courses of general science but demanded as a foundation for an intelligent reading of the press may be found."

Caldwell and Finley (3) in a study entitled "Biology in the Public Press" state, "There is need for more careful determination of the subject matter of school procedure which will be used in secondary education. It is increasingly important that efforts be made to determine the kinds of information of most use today to the body of citizens."

If we are to ascertain what kinds of information would be most useful it seems wise to first examine some of the kinds of information that the public is now using. The newspapers appear to be more up to date than our high school texts or our college texts. Much of the material in newspapers lacks careful evaluation. The writers have assumed that the material in standard magazines is more carefully evaluated than that in the daily press and therefore selected magazines as the basic source of material for this study. An examination of the scientific articles in such standard magazines would indicate what science articles the future citizens should be able to read if they are to keep well informed of the progress of science in this era. Otis W. Caldwell (4) says, "One of the heaviest obligations on modern science requires that it shall organize and present many of its results so that these results may be understood and seen by intelligent but non-scientific persons."

[1]Most of the work of preparing this article was done by Mr. Searle.

The problem of this study may be restated as the determination of what scientific information the public pays for in standard magazines, together with a statement of the relative amounts of material devoted to the various sciences.

The following magazines were selected: The Literary Digest, The American, The Review of Reviews, Current Opinion, The Saturday Evening Post, The National Geographic, The Atlantic, Scribners, The World's Work. Then it seemed best to include one magazine devoted entirely to science. This magazine was to be used as a check in order to discover whether the same topics were given space in both kinds of magazines. For this purpose the official organs of the association for the advancement of science was used, namely Science and Scientific Monthly.

The files for the ten-year period from Jan. 1, 1914, through and including December of 1923 were examined. All articles dealing with scientific material were read. The entire ten year files were available for all of the magazines except the Saturday Evening Post, for which only five years and six months were available. Five years of Science and five years of Scientific Monthly were read.

The subscription list for the magazines follows:

American	2,251,000
Atlantic	127,982
Current Opinion	103,900
Literary Digest	1,380,000
National Geographic	906,617
Review of Reviews	200,000
Saturday Evening Post	2,250,000
Science	11,000
Scientific Monthly	8,000
Scribners	71,414
World's Work	140,000
Total	7,349,913

The above table is included to show to what extent the magazines circulate.

The basic criteria for the selection of articles were as follows:

1. Does the article contribute to the background needed for an intelligent understanding of the principles, discoveries, and inventions of science?

2. Is the article in close relation to the interests of pupils in regard to science and will it contribute to the satisfaction of the scientific interests of adults?

3. Will the article make a contribution toward a scientific attitude on the part of the reader?

Each article which met one or more of the above criteria was selected, the total column inches occupied by it were measured and recorded together with the title, source, date of publication, the page, and the author (where available). The same procedure was followed with all of the articles selected. Since the columns in the several magazines were not the same width and since the type used was not uniform as to size in all cases, some other measure than column inches had to be used in order to make the figures for the various articles comparable.

This difficulty was met as follows: a thousand column inches were selected at random in each of the various magazines. The average number of words per column inch was then determined. This factor was multiplied by the recorded number of column inches for each article. The product was taken as the number of words in the article. Thus it was possible to put all the articles on a common quantitative basis which could be used in making comparisons.

The articles, as selected, contained material on the following subjects which are usually called science subjects in the high school: physics, agriculture, chemistry, and biology. There was a small surplus of material which did not relate more to one science than to another; this material was called *general*. This material called general should not be thought of as "general science" in the sense of the high school subject designated by that name.

The articles in each subject were classified into topical groups. The groups used were those commonly called major topics in high school text books. The first tabulation showed the distribution of the material by topics and by magazines. The resultant tables are too large to be included here, therefore only the percents of material on each topic are given. For complete data see Masters' Thesis of Albert H. Searle, in education library of Iowa State University.

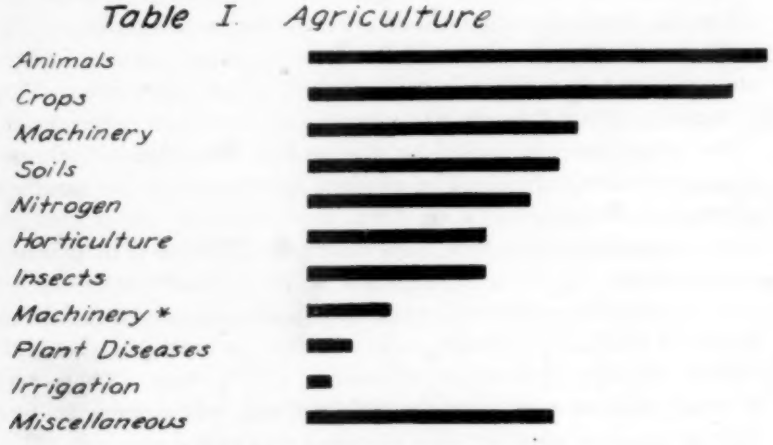
TABLE I. AGRICULTURE.

	Percent.		Percent.
Animals	19.3	Insects	6.4
Crops	17.9	Machinery	4.4
Machinery[1]	11.4	Plant diseases	1.9
Soils	10.7	Irrigation	1.0
Miscellaneous	10.3		
Nitrogen	9.3		100.0
Horticulture	7.4		

[1]Means stationary machinery.

TABLE II. PHYSICS.

	Percent.		Percent.
Dynamos and Machines	16.5	Magnetism	3.8
Light	18.2	Sound	3.3
Matter	10.5	Gravity	2.6
Mechanics and Work	8.9	Electrostatics	2.4
Heat	8.2	Energy	1.7
Mechanics of Solids	6.6	Electric induction	1.2
Molecules	5.1	Electric current	1.1
Men	5.0		
Mechanics of Liquids	4.9		100.0



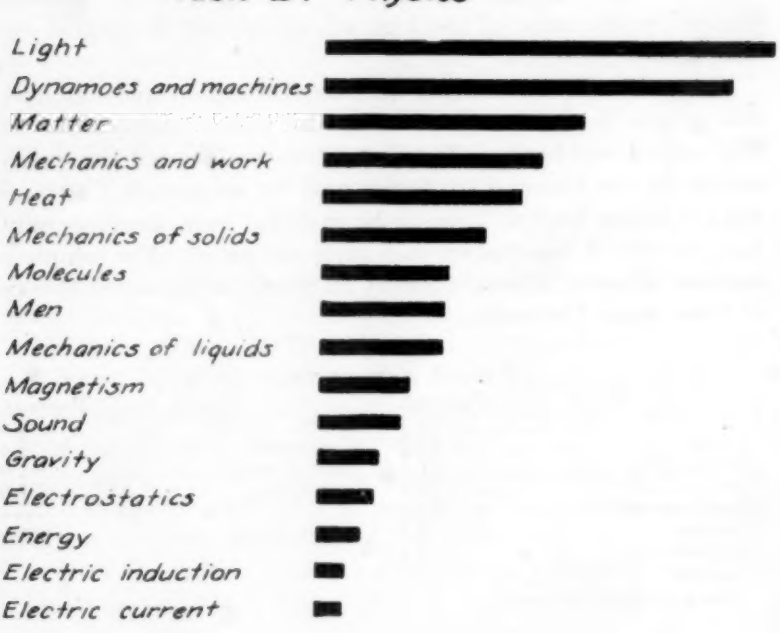


TABLE III. CHEMISTRY.

	Percent.		Percent.
Processes	14.9	Colloids	2.2
Discoveries	12.9	Men	2.1
Gases	12.8	Crystals	1.2
Synthesis	11.2	Salts	1.2
Atomic weight	7.4	Periodic system	0.8
Analysis	6.9	Organic chemistry	0.5
Sodium	6.6	Sulphur	0.5
Nitrogen	4.5	Symbols	0.5
Radium	3.9	Calcium	0.4
Laws	3.8	Halogens	0.3
Oxygen	2.7		
Acids	2.6		100.0

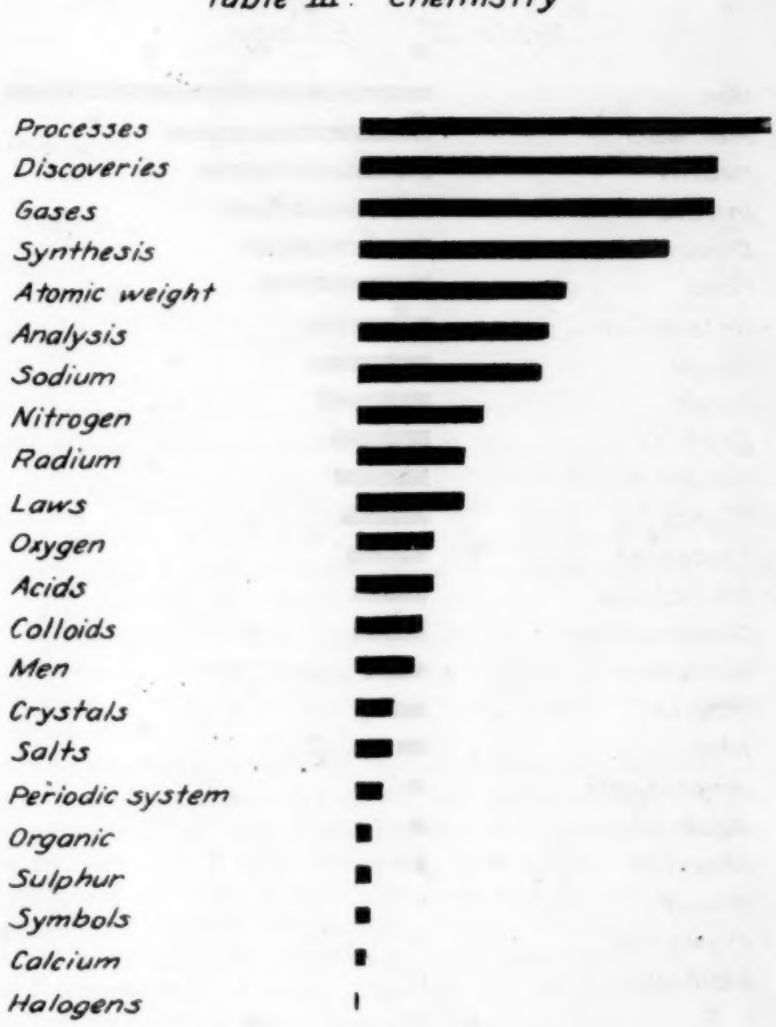


TABLE IV. BIOLOGY.

	Percent.		Percent.
Man	17.1	Microscope	2.0
Mammals	10.5	Conservation	2.9
Health	9.2	Evolution	2.5
Insects	8.2	Plants	1.6
Disease	7.2	Men	1.0
Food	6.7	Amphibians	0.7
Respiration	5.0	Absorption	0.5
Fungi	4.9	Crayfish	0.3
Birds	4.3	Blood	0.1
Reptiles	3.9	Digestion	0.1
Bacteria	3.6	Mollusks	0.1
Fishes	3.5		
Processes	3.2		100.0

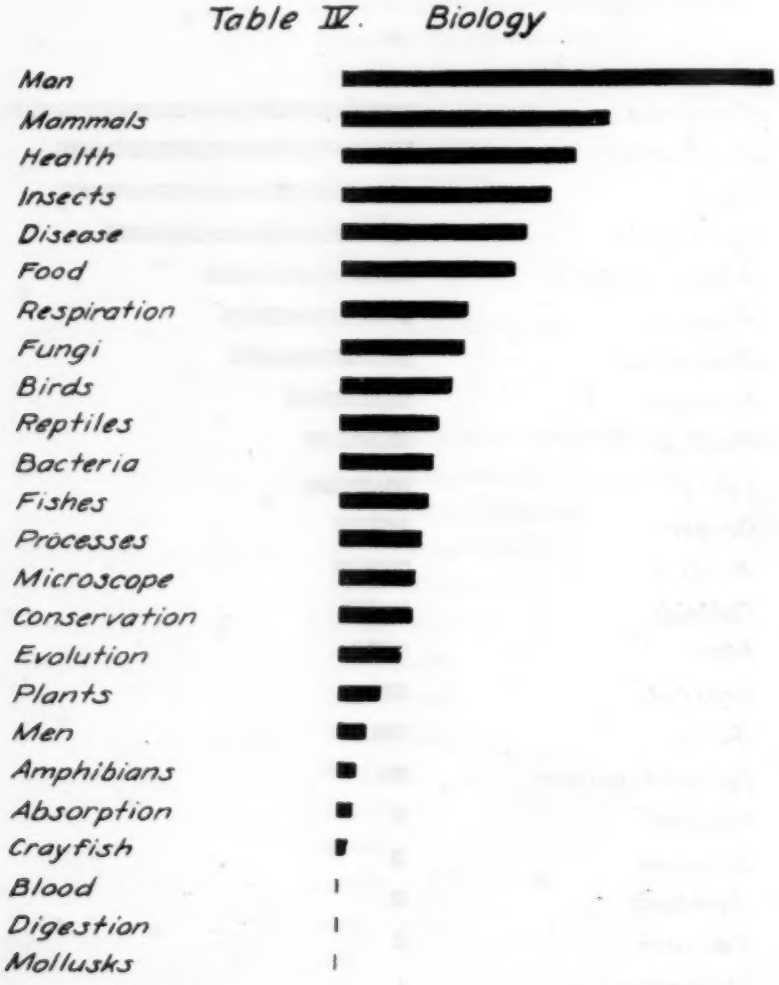


TABLE V. GENERAL.

	Percent.		Percent.
Physiography	39.3	Meterology	1.9
Physiology	28.9	Household	1.1
Textiles	16.2	Animals	0.9
Astronomy	9.2		
Food	2.5		100.01

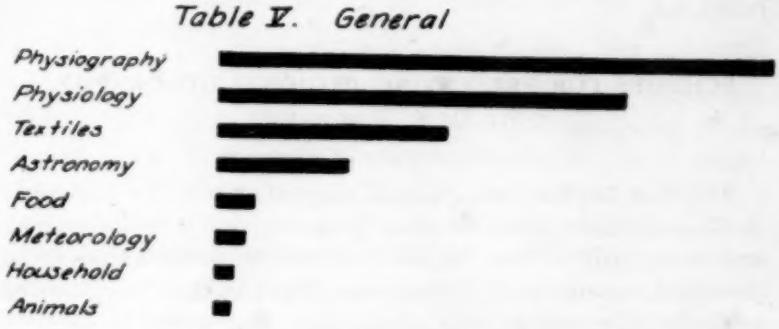


TABLE VI. GRAND SUMMARY OF MATERIALS.

Sciences	Words	Percent.
Agriculture	118,971	2.4
General	199,495	4.0
Chemistry	264,309	5.1
Physics	1,278,962	26.3
Biology	3,161,110	62.2
		100.0

The first five tables have been converted into bar graphs as the relationship is more easily seen in that form.

Curtis (2) found in his study of Newspaper Science that 41.4 percent of the articles were on biological science and 49.0 percent were on the physical sciences. The present writer's findings indicate a much larger proportion devoted to biological than to physical sciences.

It is evident from the tabulation that the magazines studied contained articles on the major topics of each of the high school subjects. The quantity found on the topics under each subject varied widely.

The conclusion cannot be drawn that because a certain percentage of the articles was found for any one topic under any one subject, that the percentage therefore indicates the relative importance of the topic. Since these topics are treated in the magazines, that circulate so widely, it seems that the school should prepare the pupils so that they will be able to interpret the material covered by the articles, especially those topics given the larger percentages of space. These findings may be taken only as one indication of what the pupils should be able to interpret.

BIBLIOGRAPHY:

1. GRUENBERG, BENJAMIN C.: "Unifying the Aims of Science Teaching," School and Society, Vol. 21, Jan. 31, 1925.
2. CURTIS, FRANCIS DAY: "Some Values Derived from Extensive Reading of General Science," Columbia Contributions to Education, No. 163.
3. CALDWELL, OTIS AND FINLEY G.: "Biology in the Public Press," Lincoln School, Teachers College, Columbia University.
4. CALDWELL, OTIS AND SLOSSON E.: "Science Remaking the World," Doubleday.

SCHEMES FOR PRESENTING REGIONAL GEOGRAPHY.[1]

BY D. S. WHITTLESEY,

The University of Chicago.

The title implies that regional geography may be presented in the same fashion for audiences grown-up and juvenile, trained and untrained; it even implies that all the world agrees as to just what regional geography means. Each of these implications might be discussed to such length that there would be no time left for setting forth schemes for presenting regional geography. Therefore, I shall take a short-cut to my subject by arbitrarily defining regional geography and selecting the audience. I conceive geography to concern itself with relationships between activities of human life and aspects of the natural environment; hence regional geography is the study of those relationships in a particular area. Ideally, the area should be characterized throughout by uniformity of relationship between the natural environment and human activities. A region so unified is my notion of a "geographic" region. It is with the presentation of the regional geography of geographic regions that I propose to deal. The audience in which my thoughts on the subject have crystallized is the intimate class of graduate and fourth-year undergraduate students who have already pursued from three to a score of college courses in geography. I shall state my conclusions here much as they might be stated to such a group, leaving you to apply them to the particular audiences with which you have to deal.

To keep the subject firmly planted on the ground, where presumably geography ought always to be fixed, I propose to use for illustrative purposes Africa. Africa has been so little studied by geographers that conclusions may be drawn there without prejudices derived from established theories; moreover it is remote enough from common knowledge so that confusing details of facts will not upset the orderly evolution of theory.

[1]Read before Geography Section of the C. A. S. and M. T., November, 1925.

SCHEME I.

If we can agree, for the purposes of the discussion, that geography deals with the relations between natural environment and human activities, we may logically present the items of the natural environment seriatim, relating each to conditions of human life. Suppose we try this scheme for the Abyssinian Highland region.

(a) This is a region of lofty plateaus, set off sharply from surrounding lowlands by steep escarpments, except on the southeast, where the barrier is formed by an exceptionally barren desert. As a consequence of being perched above and separated from the surrounding people, the Abyssinians always have been isolated, they have developed a self-sufficient economy, and they have been able to maintain social and political independence. Within the region gorges and mountain ranges separate the plateau into three principal parts, which have had diverse histories, and which today differ in social structure and economic advancement. The broken character of the country greatly handicaps transportation.

(b) The climatic variation of major importance is vertical. Abyssinians recognize three types—hot, moist lowlands up to 6,000 feet, even-tempered, warm lands between 6,000 and 8,000 feet, and cold lands above 8,000 feet. In the lowest zone sugar cane, bananas, and cotton may be grown, but the population is very sparse, due to danger from malaria and sleeping-sickness; in the middle zone wheat, barley, grapes, and most other middle latitude crops can be grown, and there most of the people live; in the upper zone grazing is the chief occupation, although a few hardy cereals may be raised, and the population is not dense.

(c) Chief among the natural resources is the soil, which is more fertile than most parts of lowland low-latitude Africa—perhaps as suitable for crops as average soils in eastern United States. Tillage, therefore, has progressed farther than among most African groups, and the whole social and political system is based on land. Most of the natural vegetation has been removed. As woods now cover the more remote, steep slopes, it is supposed that all slopes were originally forested, but most of the woods have been used for fuel. Settlements commonly are located near forests, being transplanted as the wood supply retreats. Most of the area not under crops is grassland, which affords excellent grazing grounds. The native animal life has become extinct along with the vegetation on which it throve. In the stream-

valley jungle conditions are little modified, and in a few thickets on the upland elephants exist, but the native life of the plateaus is mostly replaced by cattle, goats, and sheep, of which there are large numbers. The surface waters are unsuitable for navigation, but streams may be used for irrigating certain piedmont plains, and there is a large amount of potential water power. Little is known of the mineral wealth, but since the region is made up mainly of recent lavas, any valuable minerals are very deeply buried, if they exist. Stone is plentiful, and is the principal building material of the region.

(d) While not a large region, the Abyssinian Highland is large enough to produce much more than it does, of crops, animals, and forests. Its location near the Straits of Bab-el-Mandeb, one of the principal foci of the important trade route between Europe and Asia-Australia, offers notable advantages for participation in world trade, but at present the escarpment, the desert which separates the Highland from the sea, and the lack of satisfactory outlet harbor, make costs of transport so high that the only exports are hides, skins, beeswax, coffee, and civet.

This sketch of Abyssinian geography from the angle of the natural environment, gives an orderly and complete picture of the principal conditions of the environment, and a definite statement of those human activities which are directly related to the earth conditions and resources. I believe, however, that you have not obtained from it a well-rounded picture of those human activities. Let us consider the same region from the angle of human life.

SCHEME II.

(a) Economic life in the Abyssinian Highland is based on land, made possible by the facts that the soil is fertile and the climate provides a long growing season with abundant rain and a long ripening and harvest season of drought. The farmer is not only a planter but also a herder, since some of the land is too steep and some too cold to permit satisfactory tillage. His methods are very crude, for his isolation in a desert-girt, cliff-faced plateau has minimized contact with the outside world and created an attitude of hostility to new-fangled inventions. He raises cereals for his food staple, cattle, goats, and sheep for meat, milk, wool, and skins, and bees for honey, wax, and the basis for his national alcoholic drink. Internal communication is very meager, for the plateau is much dissected by deep gorges and blocked by mountain ranges. Nevertheless, goods do find their

way to the borders for shipment, and there towns have developed. These towns are mere hamlets except during the market season, which is the dry season when the torrential mountain streams are low, but then they swell to cities of 40,000 or 50,000 inhabitants. The only items which can bear the high cost of transport by mule and camel pack or by the one pokey railroad, are hides, skins, wax, coffee, and civet. In return arms and ammunition are purchased by the warlike people, who are bound to retain the independence they have won in a mountain environment, and some textiles and other manufactured goods of Europe are imported.

(b) The social life is that of all small communities that gain a livelihood by agriculture and are compelled to maintain a permanent defense against aggressive neighbors. It corresponds to that of feudal, medieval Europe. The church is the dominant institution, owning almost a third of the land, including in its ranks one-quarter of the adult males, and operating an important monastic system. The peasants are serfs, and the ruling class is a military caste. Traders and artisans are culturally distinct and are despised by the land owners. These conditions reappear the world over among peoples just emerged into settled agricultural life from subsistence by exploitation of natural resources.

(c) Political independence is a striking feature of Abyssinian life, because it is unique in Africa. It was made possible by the easy defensibility of the region, by the age-old practice of war among the communities of the broken plateaus, and by mutual dissensions among European holders of the neighboring lowlands, none of whom was willing to see another in control of the highland—at once a stronghold, a source of wealth, and the potential controller of Nile flood waters. A considerable measure of internal political dissension still exists, traceable to the separatism of the whole region into at least three distinct plateaus.

The advantages of this mode of presentation include concentration of interest where most people feel it, viz., on human life, and completeness in picturing the life of the region. Manifestly, it does not completely cover the natural environment.

Scheme III.

A third scheme of presentation would set forth in series the relationships which exist between natural environment and human activities. Since these relationships are abstractions, I confess that I find it impossible to present them at all, except as they grow out of facts of the environment, or the life of the

people. Therefore, as an alternative to this third logical type of presentation, I submit a presentation which will bring out the more important relationships. This may require starting with a fact of the human activities or with a fact of the natural environment, to be determined by the conditions of the particular region under consideration.

The Abyssinian region is characterized by self-sufficient remoteness. This appears most clearly in the political independence of the region, the only territory in Africa self-governed in spite of covetous European states which have seized far less productive lands. The isolation of the region, perched on lofty plateaus with steep escarpments, and girt by deserts, has tended to differentiate the Abyssinians from their neighbors, and the highland is a natural fortress, easy to hold against assailants from any side. Moreover, the moderate yet varied produce of the land has made it unnecessary for Abyssinians to form a commensal economic connection with outsiders.

This military invincibility has been fostered by traditional internal warfare in a region notably dissected by deep gorges and broken by mountain ranges. The several districts within the plateaus have developed in an atmosphere of mutual hostility. This is reflected in the imports, chief among which ranks arms and ammunition, and in the lack of roads and bridges to link up the several parts of the region.

Remoteness from the outside world and divisive land forms have compelled each small district to become as nearly self-sustaining as possible. This has stressed the importance of land, from which most of the bare necessities of life are derived, and in the Abyssinian Highland the land is more productive than in most of low-latitude Africa. This is partly because the soils are naturally fertile, being derived from lavas rich in mineral plant foods and being constantly renewed by rapid erosion and replaced by rapid weathering. Another factor in the usefulness of the land is climate, which provides a regular recurrence of abundant rains, favorable for growth, and dependable drouth, ideal for maturing and harvesting of crops. Moreover, the climate varies notably with altitude, ranging from hot and wet below 6,000 feet, through warm and moderately dry between 6,000 and 8,000 feet, to cool and moist above 8,000 feet. The low-lying lands can produce rice, cane, and cotton, the medium elevations maize, wheat, grapes, and nearly all other middle latitude crops, and the highest lands are excellent for grazing, and can grow hardy cereals.

Whereas land is of more than average productivity, other resources are wanting or are difficult to develop. Useful minerals, other than stone, are deeply buried if they exist at all. There is much water power, but its development would require heavy outlay of capital. Neither streams nor lakes can be used for navigation, but rather are formidable barriers to transport and communication.

The economic and social system growing out of these environmental conditions is feudal or manorial, especially in the major highland. Livelihood is gained from the soil by peasants who are serfs. The landowners constitute a governing and fighting caste. Traders and artisans are ethically and culturally distinct, and are despised by landlords and peasants alike. The church is the most powerful institution in the state, owning one-third of the land and having a monastic as well as a secular establishment. Farm practices are primitive, as the Abyssinian is out of touch with the world.

Manufacturing is confined to the simple trades of the smith, the carpenter, the mason, and the leatherworker, and to household fabrication of cotton and woolen clothing. The importance of the mason arises from the abundance of building stone and the scarcity of timber, all the more accessible forests having been cut off for fuel. Indeed, it is the custom to move villages and even the chief towns whenever the local fuel supply becomes exhausted.

Trade is small in volume and concerns itself mainly with exports and imports. The chief item of surplus is hides and skins from the numerous cattle, goats, and sheep that graze on lands too steep or too cold for crops. Beeswax, coffee and civet make up the short list of exports. All are valuable, imperishable, and easily adaptable to the varying types of transport used. Mules are employed on mountain trails and camels on the surrounding desert. The one railroad follows the easiest route to the sea which it reaches at an exposed harbor. Trains are run by day only, because of danger from bandits. On the plateau, near the head of each main trade route, lies a commercial town. Except for Addis Abeba, at the terminus of the railroad, these are mere hamlets throughout the wet season, when the roads are impassable. During the dry season fairs are held, and the towns expand to several thousand temporary inhabitants. The only exports that can bear the high cost of this primitive trading organization are skins, beeswax, coffee, and civet. The chief imports are am-

munition and weapons, needed by a people living in feudal confusion, and certain luxuries of manufacturing Europe.

Presentation from the angle of relationships between environment and life compels some duplication in statement, and lacks that precision given by a rigid order of topics. It gains flexibility and completeness in treatment, and more than all, it subordinates neither the natural environment nor the human activities. Moreover, it brings to the fore the personal element, as no two students of a region would be likely to follow exactly the same order of topics. Whether this is an advantage or a handicap might be subject to dispute.

Choice of mode of presentation may well differ for different regions and for different audiences. Each has points in its favor and points to its detriment. Probably only a considerable period of experimentation with the several schemes can determine the ultimate favorite.

THE TRAINING OF SCIENCE TEACHERS.

By Chas. W. Finley,

The Lincoln School of Teachers College, New York City.

The question of teacher training for our secondary science teachers is not one of subject matter *or* professional training but one of subject matter *with* professional training.

No doubt a recent article[1] by one of America's leading physicists relating to the training of science teachers for secondary schools will add volume to the long standing controversy between "academically minded" and "professionally minded" educators interested in this subject. Dr. Millikan's ideas are more tempered toward the value of pedagogical courses than are those of Dr. True, who says: "As the true artist must paint, the true poet write poetry . . . . . the true teacher must teach. How should teachers be trained? In my judgment it is best to let them train themselves by teaching. To subject such to courses on how to teach would not only be unnecessary but undesirable."[2] He advocates that science teachers prepare themselves in pursuit of science knowledge, with the idea that the professional side will care for itself.

It is not difficult to find expressions of the opposite viewpoint. T. M. Balliett, for example, says:

[1]Millikan, R. A. *The Problem of Science Teaching in the Secondary Schools.* School Science and Mathematics XXV. 966-75, 1925. Also School and Society XXII:633-39, 1925.

[2]True, R. H. *The Training of High School Teachers in Biology.* Proceedings, Tenth Annual Schoolmen's Week. pp. 255-59, 1923.

"My contention is that graduate instruction in our universities does virtually nothing to fit the teacher to teach either science or mathematics in a vital way in our secondary schools. It may even be possible that a highly specialized training of the graduate school, to a certain extent, unfits the student to do this sort of teaching. However, that may be, I state a well-known fact when I say that not one in fifty of men and women who take the Doctor's degree in science or in mathematics has the least conception of the problem before him when he begins teaching in a secondary school."[3]

"The opinion is still prevalent that our elementary teachers need special training, but that the secondary teacher is such by the grace of God and the authority of one's 'alma mater.' Over against this view should be set the demand that the secondary school teacher shall have professional training." (E. E. Brown)

"What we most need is a crop of science teachers with a large fund of constructive imagination, who have been trained by college and university professors who bow somewhat less reverently before the shrine of research and realize rather that the kingdom of heaven can be found in the lives of growing boys and girls." (J. E. Peabody)

"The prospective teacher needs, first of all, to gain a working conception of the correlative nature of scholarship and method. A true synthesis is to be found in a masterly control of subject matter in the process of education. Three elements, at least, are involved in adequate teaching; they are, gripping boys and girls understandingly, using subject matter with a functional outlook, and gripping ways and means of directing activity in a productive manner. The *whats* (subject matter) to teach must include the complicated and variable *hows* (method) of teaching. Any mechanical separation between academic scholarship and professional training courses must be bridged. The notion that one first acquires subject matter—amasses information, and then acquires methods of teaching it, is held to be invalid, and an unfortunate separation." (H. L. Miller)

"It is still believed by otherwise well-informed persons that any scholar is *ipso facto* a teacher, or, at least, that he can easily become a teacher—a good one—by practice only. (It would be more correct to say by floundering!) This view is held, with a conspicuous disregard for the testimony of experience, by

[3]Finley, C. W. *Biology in Secondary Schools and The Training of Biology Teachers.* Bureau of Publications, Teachers College, Columbia University, 1926.

many college professors. Inasmuch as colleges and universities are the source of supply of the great majority of our high school teachers, the persistence of this error must be reckoned with when we seek to secure proper training for high school teachers. . . . Teaching power, like scholarship, must be acquired with painstaking care. . . . The 'born' teacher . . . gains enormously by the careful study of every detail of his art or profession." (P. H. Hanus)

There is general agreement among educators in both "academic" and "professional" groups that a science teacher, or any other teacher, should be well informed in the subject matter of his chosen field. The real issue is whether in addition to or along with his pursuit of subject matter he shall also do "professional" work. The professionally minded educators do not decry subject-matter preparation but insist that in addition to it, the teacher shall pursue courses which will better prepare him to teach this subject matter to high school students in a more efficient manner. Dr. Millikan's "learning by doing" is surely as applicable to the acquisition of teaching technique and skills as it is to the acquisition of subject matter and attainment of the scientific method. The teacher in training needs to learn the technique of teaching by *doing* just as the research worker in training needs to learn the technique of research by *doing*. Practice in classroom teaching under guidance of masterful teachers bears the same relation to teacher training as does laboratory practice and research under competent guidance, to the training for research. It is just as scholarly, no more no less, for the teacher to know and study the problems of teaching as it is for the specialist to know and study the problems of research.

The fact that knowledge of subject matter alone is not sufficient to insure good teaching is well shown by signal failures as teachers of some noted scientists in science departments of our higher institutions. Teaching, to many of these men, is but a waste of time and an interference with research work. The welfare of the nation and of posterity depends, to a large measure, on the time consuming, carefully planned, and intelligently applied research work of these specialists. It is neither a just nor intelligent demand that these men train teachers. Their task is to do research work and train research workers.

In addition to acquisition of subject matter and participation in teaching, there are many other topics, devices, skills and

considerations which should be brought to the attention of the prospective teacher. The question of subject matter for high school courses in science is an important one. Shall the organization of subject matter in introductory courses differ from that of later courses? What are the arguments for and against general science as an introductory course? Should the aims and purposes of introductory and advanced courses differ? Should there be any attempt to relate science courses to other courses in the school such as industrial arts, household arts, mathematics and others? What has been the history of the changes in aims and purposes of science teaching in the high school? What disposition shall be made by the teacher of some of the state requirements regarding topics to be taught in some of the subjects—alcohol, narcotics, tobacco, evolution and others?

There are three types of laboratory procedure applicable to science work in the high school; individual work, group work, and teacher and pupil demonstration. Which type of procedure is best fitted for work in general science, botany, physics and the rest? Shall the same type of laboratory procedure be used in science classes, in academic, and commercial groups of students? What shall be the relation of laboratory and class work? The laboratory note book with its problems of notes, labellings, drawings, diagrams and the great amount of time required to properly supervise and correct, well merits consideration of students who expect to teach science. There are many other topics concerning the laboratory worthy of consideration. A few such are: collecting and preserving materials, purchase of supplies, making of microscopic and lantern slides, operation of projecting apparatus, and others.

Literature and references best fitted to the high school student should receive the attention of the prospective science teacher. There is a wealth of such material in science. In addition to the usual books and magazines there are national and state bulletins and numerous pamphlets by commercial and industrial companies, educational, and philanthropic organizations. The *Research Narratives* of the United Engineering Society; *Chemistry in Industry*, by The Chemical Foundation, Inc.; *Birds of Massachusetts and New England*, by the Massachusetts Department of Agriculture, and the numerous health pamphlets by the Metropolitan Life Insurance Company are cases in point. An intelligent use of these references

will greatly enhance and vivify the high school science courses.

No doubt, the antagonism of some research specialists to professional courses dates back to a knowledge of types of such courses a few years ago. Many so-called "method" or "teachers" courses of this period comprised a few weeks of cramming in the various subjects in order to "pass" teachers' examinations and thereby gain the coveted certificate to teach. Little or no attention was given in these courses to a consideration of really professional matters. The effect of such practice could but result in sending into the field narrow, unscholarly, and poorly-prepared teachers. We must not forget that even these get-teacher-quick methods failed to prevent teacher shortage. Hence some justification and credit should be given to these courses. But this is beside the point.

The men most interested in the professional training of high school teachers are as zealous in their advocacy of scholarship as are those in the liberal arts field. Surely the growing youth of the nation is a more valuable asset than are any of the commercial commodities which today command such a large amount of scientific research. The best men obtainable are none too good for science teachers in our high schools. May salaries, teaching schedules and tenure, improve to the point where science teaching will be as appealing and as respectable as subject-matter research!

The problem of training teachers for science work in our high schools of today is further complicated because of the tasks imposed on these teachers. Were the teachers trained in chemistry or physics, or biology, assigned to the teaching of that subject and that alone, the problem of teacher-training would be much simplified. The fact that more than half the teachers in science in our high schools are teaching three or more different subjects, acts as a deterrent to idealism and, no doubt, to acceptable teaching of these subjects. A résumé of several studies of science teachers and their tasks is found in the accompanying table:

From these studies we are led to conclude that approximately ten per cent of our science teachers teach but a single subject; thirty per cent teach two subjects; thirty, three subjects; twenty, four subjects, and ten per cent teach five subjects in the high school.

Some of the studies reported the subject-combinations of the teachers investigated. As would be expected the list in-

SCIENCE TEACHERS AND THE NUMBER OF SUBJECTS THEY TEACH.

Investigator	Number of teachers reported	Per cents of teachers teaching given number of subjects.						
		1	2	3	4	5	6	6*
Caldwell	48	6	31	40	19	4	....	.
Cummings	31	22	26	22	26	3	....	..
Downing	70	1	26	30	21	10	10	1
Finley	129	17	41	25	15	2	....	..
Hutson	270	8	26	31	23	8	3	1
Foster	144	17	28	22	21	10	1	..
Montgomery	61	8	30	34	18	10	....	..

cludes all the subjects expected to be found in the high school curriculum. In the main, the teaching schedule is a combination of science subjects. If these science teachers taught nothing but science subjects, more than half of them, as is shown by the investigations, would need preparation in three or more sciences in order to meet the tasks confronting them. It is not the intention of the writer to champion this state of affairs. Such a condition is deplorable and can only result in a corps of teachers who are acceptably prepared, neither in subject matter nor in professional aspects of the subjects they are teaching.

The question of teacher training for our secondary science teachers is not one of subject matter *or* professional training but one of subject matter *with* professional training. Best results will obtain when our teachers have the optimum amounts of each. If the liberal arts college is desirous of having its graduates enter the teaching field it should provide practice teaching facilities and professional courses for those of its students intending to teach. Likewise, teachers colleges should so organize their work that graduates from these schools are well-grounded in subject matter. Each type of institution, then, should send into the field teachers well trained in the subject matter and professional aspects of the subject he intends to teach.

A course in X-ray technique is offered for women by Hunter College, New York City. Applicants must be graduates of a recognized training school for nurses, or have one or two years of professional experience in medical, dental, or health work, in addition to completion of three years of high-school work, or its equivalent. The purpose is to train X-ray technicians as assistants in doctors' or dentists' offices or in X-ray laboratories or clinics, and prepare students to take charge of the technical aspects of X-ray work.

TRANSPARENT TUBES FOR EXHIBITING SKINS.

A METHOD OF PRESERVING THE "LIFE" OF STUDY-SKINS.

BY ROLAND CASE ROSS,

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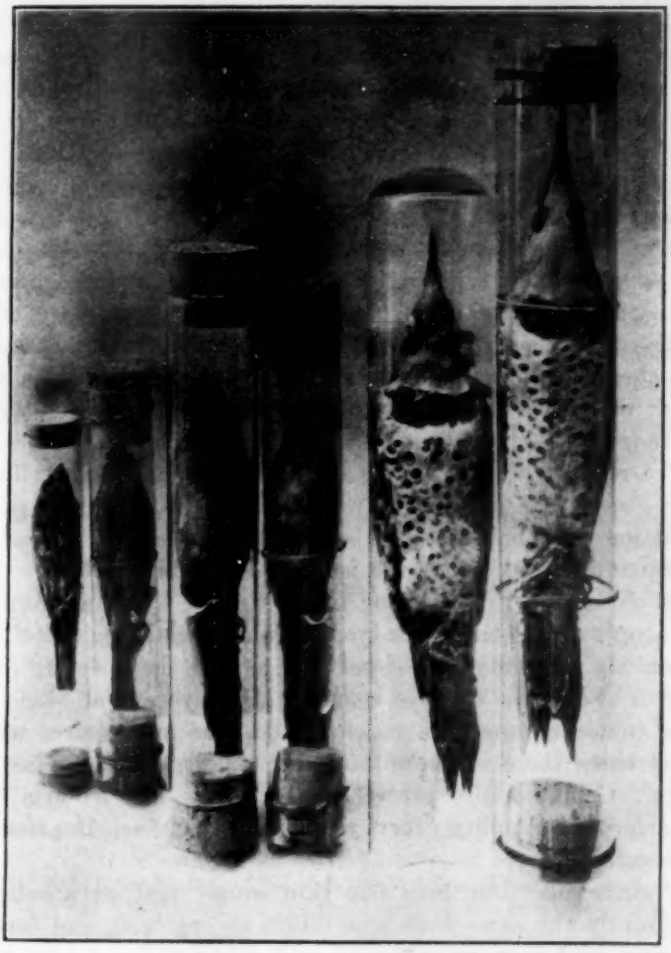
The use of study-skins of birds in popular classes and in the grammar schools is seemingly on the increase. The study-skin has certain advantages over both pictures and mounted birds which make it a practical and desirable accessory in classes studying birds from the identification standpoint. There are disadvantages of course; such as unnatural shape and attitude, concealed colors or marks, probable damage from student handling. There are those who will use no unmounted skin in such work feeling that the "mummy" specimen gives a distorted impression. They insist that any mounted bird, even a wretched one, is better than a study-skin.

In the Nature Department of the Los Angeles City Schools we do not hold to this view, as a bird mounted incorrectly has attitudes and proportions so unlife-like that it seems better to make no attempt at naturalness of pose, except with the aid of color work of real bird artists, or with photographs. A mounted bird though substantially made and life-like will not stand the handling in classes and the transportation necessary in such work and soon becomes unusable from the standpoint of distortion and injury. Hence study-skins are used entirely in our work in the schools, with the exception of those classes which visit the museum.

Skins put up for handling not only last longer and are more transportable than those mounted but have an advantage in that they may be closely examined by individual students; a mounted bird is hardly accessible to all. . . . The serious objection lies in the skin itself: it cannot stand the abuse of inexpert and careless handling. Putting the skin on a "stick" or handle, as demonstrated by Dr. Joseph Grinnell in the Condor for May, 1924, page 107, is evidently a most practical step for preserving the specimen. But in some classes it is impractical to allow students to handle the skin at all; for little children, and even adults who should have more comprehension of delicacy, treat the skins severely, though unconsciously. Most of them will pet the skin, some rub it in reverse direction, others try to open the wings or poke about in the feathers, and all pick up the skin, or hold it, incorrectly.

The genial and obliging ornithologist of a certain museum tells how a woman addressing a club meeting, dangled one of his specimens, borrowed for the occasion, by the feet. In a short time the skin "escaped" and the lady exclaimed laughingly, "O,—the legs came off." This is one of the reasons curators soon grow old.

After years of lending skins for classes Dr. Charles L. Edwards, director of the above mentioned department of nature-study, hit upon the idea of enclosing each specimen skin in a glass tube corked tightly at each end. Heavy tubes of assorted dimensions



THE RIGHT TUBE OF EACH PAIR OR SIZE SHOWN ABOVE IS OF CELLULOID; THE LEFT IS OF GLASS. NOTE THE RUBBER BANDS ON FORMER.

have been in use over a year now and are found to give splendid protection to the loaned material. A few have been broken, with no damage to the bird that I have observed.

There are objections: first, that of weight,—the tubes are heavy and it is a burden to carry more than a few, especially in the larger sizes; second, that of expense, as such glass from laboratory supply houses is costly; third, unless a skin and its tube container are a perfect fit the specimen slides back and forth ruffling feathers and jamming the tail.

In September of last year I effected tubes of good visibility, light weight, low cost, and expansive construction. Sheet celluloid, which may be had at any auto-top works, is cut to size and rolled, allowing enough surplus to lap half way around the cylinder when at the desired diameter. In place of corks, which are of tapering surface, wooden dowels are cut into cork lengths and inserted as plugs in the ends. (Doweling comes in various sizes at lumber yards.) Finally rubber bands are used for the binding element, holding the roll firmly about the plugs. The lappage allowed insures dust-proof fittings and also permits the use of the same sheet of celluloid upon larger dowel plugs for the receiving of bulkier specimens. This expansive character cuts down the amount of tube material needed to be kept on hand; with glass tubes quantities of each slightly different size are required.

The reduced weight is amazing when one compares celluloid with glass. The visibility is practically as good, though in the reduction by photography the celluloid is shown to be less transparent. (See cut.) It is not observably so to the eye. Celluloid ages if exposed long to the light. We learn from the auto-top makers that in a year's time a clouding effect will impair the visibility; we expect to replace the sheeting every year or two as the expense is small. However, as all skins and their containers are kept much of the time in darkness within metal cases there is reason to expect the material to last for years. Celluloid also scratches and wears but we feel that replacing for visibility every year or two will keep the stock in fresh condition.

A glass tube may hold one skin snugly and let another of apparently the same bulk slip. This sliding back and forth is wearing, and even ruinous. On celluloid tubes a rubber band placed directly over the thick part of the enclosed skin—that is, the breast, grips the specimen firmly and prevents all sliding.

This advantage alone makes the roll superior to the glass tube. Again it is possible to "roll up" the bird, or mammal, skin by this method, while in glass tubes the skin is pushed in and through. This means wear, for a tight fit is necessary. So, loose or tight the glass tube does some damage—though not as much as do the teachers or pupils or other students when furnished with unprotected study-skins.

A skin thus protected can be passed about a class of children or unappreciative adults and come back whole and sound. For learning color areas, marks and general coloration, shape of bill, feet, etc., and length of wings and tail this devise is satisfactory; for protecting tails, claws, etc., of mammal skins it is also effective. With small specimens male and female of the species are easily presented tandem fashion in the same tube, giving at once the differences to be found on breasts or other portions exhibited in most evident contrast; a turn of the hand brings a reverse view. For hummingbirds and shrews the glass tubing is preferable making a firmer container and giving needed protection; slippage is not observable in these small sizes.

If a responsible class, of advanced students, requires the skin in the hand it is easily removed by drawing the plug at the head end, after removing the rubber band. It is just as easily returned, head end first, of course.

A WORD TO OUR MEMBERS.

This magazine reaches all active members of the Central Association of Science and Mathematics Teachers; it serves as our common messenger and binds our activities into one continuous and unified effort which spreads abroad over many states of our nation. Active teachers of science and mathematics can enjoy the benefits and privileges of this association by becoming members and will thus receive SCHOOL SCIENCE AND MATHEMATICS for a year at no greater cost than by subscription. The officers are especially interested in those who have thus enlisted professionally even if they can attend our annual meetings only occasionally or perhaps not at all. The membership list in our annual program shows that we have a large number of regulars, these we have with us until the last roll call by the necrologist. We also have a fair number of loyal members whose names will sooner or later drop from our list because they have entered upon a new field of endeavor. Occasionally these good people write us that they are leaving our circle and why. The officers of the association would appreciate it greatly if they could account for all those whose names will not appear on the roll next year. Good reader, if you are a member and must leave us in the future write us a parting word. And while you are doing so, the membership committee will be glad to have you nominate a new member in your place. For the coming year let every member bring a member.

W. F. ROECKER,
Chairman, Membership Committee.

THE PRESENT STATUS OF THE CORROSION PROBLEM.[1]

By J. H. Reedy,
University of Illinois, Urbana, Ill.

During the past two years there have been held three symposiums on corrosion in the United States. The first was at Atlantic City, June 24-27, 1924, by the American Society for Testing Materials; the second at Detroit, Oct. 2-4, 1924, by the American Electrochemical Society; and the third at Baltimore, Apr. 6-11, 1925, by the American Chemical Society. In view of the intensive consideration thus given to the subject by the leading authorities, it seems timely to raise the question, what is the present status of the corrosion problem?

The papers and discussions at these meetings brought out the fact that the electrochemical theory of corrosion is accepted with practical unanimity in this country. In England, however, the older theory, known as the "chemical" or "carbon dioxide" theory, still has some adherents. According to the chemical theory, the presence of an acid is necessary for corrosion. In the case of the rusting of iron—for this is pre-eminently the most important case—the chemical theory assumes that a certain amount of carbon dioxide or other acidic material is present in the water, and that the acid is the primary corroding agent. The mechanism of the rusting of iron according to this theory is generally represented by the three following partial equations:

$$4\ Fe + 4\ H_2CO_3 \rightarrow 4\ FeCO_3 + 4\ H_2;$$

$$4\ FeCO_3 + O_2 + 10\ H_2O \rightarrow 4\ Fe(OH)_3 + 4\ H_2CO_3;$$

$$4\ Fe(OH)_3 \rightarrow 2\ Fe_2O_3 + 6\ H_2O.$$

Adding, the total equation is:

$$4\ Fe + O_2 + 4\ H_2O \rightarrow 2\ Fe_2O_3 + 4\ H_2.$$

It is seen that the carbonic acid involved is cyclically regenerated, so that a vanishingly small amount might accomplish an indefinite amount of corrosion. In answer to the objection that corrosion occurs in systems containing no carbon dioxide—an apparatus containing only iron, water, and oxygen, for example—some of the adherents of the chemical theory have naively countered that their theory must stand until their opponents *prove the absence of an undetectable amount of carbon dioxide*, for such an amount, according to the theory, is sufficient to account for the results obtained.

[1] This article was originally prepared as a review of Frank N. Speller's paper on "A Study of Corrosion Factors and the Electrochemical Theory" read before the Division of Industrial and Engineering Chemistry at the meeting of the American Chemical Society in Baltimore, Apr. 6-11, 1925, and later published in Industrial and Engineering Chemistry, *17*, 339-346. It has subsequently been revised, so as to review the problem of corrosion as a whole.

According to the electrochemical theory, which was first proposed by Whitney in 1903, corrosion consists primarily in the displacement of H^+ ions of the solution by the iron. The particularly corrosive effect of acids is simply due to the high H^+-ion concentrations they contain. Corrosion does take place, though slowly, in alkaline media, the amount diminishing as the alkalinity increases. Corrosion is carried on by electrical couples, the metal acting as the anode and usually an impurity present in the metal acting as the cathode. The hydrogen is first liberated on the cathode in the atomic form, and is either changed catalytically into the diatomic form or is oxidized directly by the oxygen dissolved in the water. These consecutive reactions are represented by the following partial equations:

(1) $8\ H^+ + 4\ Fe \rightarrow 8\ H + 4\ Fe^{++}$;

(2a) $8\ H \rightarrow 4\ H_2$; or

(2b) $8\ H + 2\ O_2 \rightarrow 4\ H_2O$.

Taking into account the further oxidation of Fe^{++} to Fe^{+++} and its precipitation as Fe_2O_3, we have

(3) $4\ Fe^{++} + O_2 + 4\ H_2O \rightarrow 2\ Fe_2O_3 + 8\ H^+$.

Adding these equations we have

$$4\ Fe + O_2 + 4\ H_2O \rightarrow 2\ Fe_2O_3 + 4\ H_2,$$

which is identical with the net equation according to the chemical theory.

Since both processes give the same final products, and the mechanisms postulated in both cases are more or less speculative, a choice between the two theories might appear very much of a Tweedledee-Tweedledum proposition. However, hitting upon exactly the right mechanism is more important than might appear at first thought. It is both a chemical diagnosis and prognosis, and the choice of the treatment to prevent corrosion must depend wholely upon the actual mechanism of corrosion. The electrochemical theory has gained acceptance because it gives a reasonable explanation of the phenomena of corrosion, including several which cannot be explained in terms of the older theory. No assumption in the mechanism can be truly said to be bizarre or fanciful. The only feature that anyone could call questionable is the intermediate formation of atomic hydrogen. But it should be recalled that the existence of hydrogen in the atomic or nascent state is now generally conceded. Such phenomena as reduction by nascent hydrogen, diffusion through metals, overvoltage, and so forth, can not be explained on any other assumption.

A number of facts strongly indicate the validity of the electrochemical theory. Corrosion localized around embedded impurities is undoubtedly electrochemical. The materials constituting the impurities in iron have been shown to have a lower ionization potential than iron; that is, if a cell were set up with the impurity as one electrode and pure iron as the other, the positive current would flow through the solution from iron to impurity. This explains exactly the phenomenon of pitting. The action is restricted to the neighborhood of the impurity on account of the resistance of the electrolyte.

The question comes up: In the light of the electrochemical theory, should homogeneous metals, not in contact with other metals, corrode? and if they do corrode, how can the corrosion be electrochemical? It has been shown that potential differences do exist in apparently homogeneous metals. Inequalities due to incomplete annealing and strains due to machining are generally present, and sooner or later lead to the formation of local patches of rust, and then the "rust proceeds to eat up the iron."

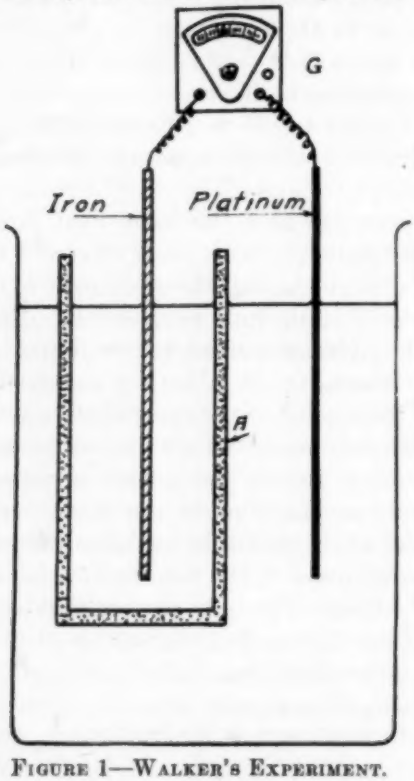


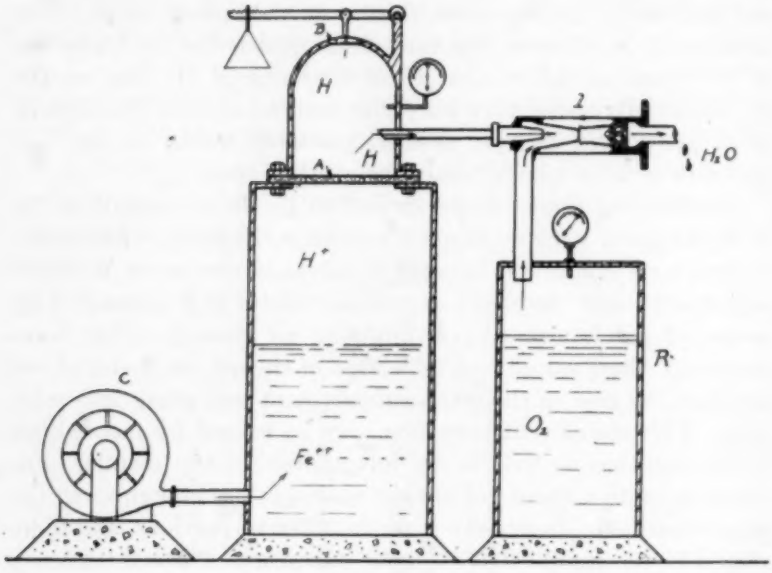
FIGURE 1—WALKER'S EXPERIMENT.

What appears to be a crucial experiment in favor of the electrochemical theory was carried out by W. H. Walker. The apparatus consisted of a cell having one electrode of pure iron and the other of platinum. (See figure 1.) An unglazed porcelain cylinder was placed around the iron, so that the electrode solutions might be kept apart. If acid were added to the compartment containing the iron there would be very little increase in action and the galvanometer needle would not move. But if the acid were added to the compartment containing the platinum, the galvanometer would instantly show the passage of a current, and bubbles of hydrogen would form on the nobler metal. This shows with definiteness that the action consisted of the formation of Fe^{++} ions at the iron, and the discharge of H^{+} ions on the platinum. By using very pure zinc instead of iron, this experiment gives even sharper results, probably owing to the fact that zinc is more nearly homogeneous than iron.

Another experiment quite similar to this was carried out by U. R. Evans of King's College, Cambridge, England. Two strips of iron were connected through a galvanometer as in Walker's experiment, and the electrode compartments were separated by means of parchment. Upon bubbling air through either compartment, there would be a deflection of the galvanometer showing that the iron in the *other* compartment was going into solution. This shows that corrosion may be caused by inequalities in the solution as well as by inequalities in the metals. For water in motion there are always considerable differences in the concentration of dissolved oxygen in different portions, and there should be no wonder that even the purest iron shows a tendency to corrode under such conditions.

Frank N. Speller of the National Tube Company of Pittsburgh and R. E. Wilson of the Standard Oil Company have worked out a diagrammatic representation of the process of corrosion, borrowing ideas from familiar mechanical processes. The following is a modification of their scheme. (Figure 2.) Suppose C is a rotary pump, driven by a constant power motor, sending Fe^{++} ions into the solution in the adjoining vessel and forcing H^{+} ions out through the dome H as monatomic hydrogen. This hydrogen may be removed as water by means of the injector I, which is operated by oxygen from the reservoir R. In the event the pressure of oxygen in the reservoir is not sufficient to remove the atomic hydrogen as fast as it is formed, the pressure in the dome may increase until it will lift the pop-off valve B and escape as

ordinary diatomic hydrogen, the pressure required depending upon the weight on the lever. In this allegory, the motor represents the ionization tension of the iron,—a constant force for a given sample. This force, however, may be considerably reduced by substituting an iron alloy having a lower ionization tension, like duriron or stainless steel. Further, the hydrostatic pressure (that is, the *concentration*) of the Fe^{++} ions may reduce the efficiency of the pump. The back pressure of the atomic hydrogen, owing to its slow removal from the dome D,



also acts as a check on its action. On the other hand, the load on the motor may be considerably lightened by having a high pressure of H^+ ions on the diaphram. This would result in the H^+ ions tending to diffuse through into the atomic form more rapidly, thereby reducing the back pressure of the Fe^{++} ions on the pump. The speed of the removal of the atomic hydrogen by the injector will depend both on its own pressure and the oxygen pressure (*concentration of dissolved oxygen*) in the reservoir. The pressure in the dome may be speedily relieved if the pop-off valve works at a low pressure (corresponding to the presence of a metal or impurity with a low hydrogen *overvoltage*).

It must be admitted that there are certain influences affecting corrosion that cannot be included in this diagrammatic scheme.

The action of passivating agents like chromates, the shielding action of films of oxide, collodial influences, motion of the electrolyte, and possibly other effects are not shown.

From the above it will be seen that the influences affecting the corrosion process may be classified as follows:

Accelerators.	*Inhibitors.*
High purity of iron	Alloying of iron
High H+-ion concentration	Low H+-ion concentration
Low hydrogen overvoltage	High hydrogen overvoltage
High concentration of dissolved oxygen	Low concentration of dissolved oxygen
Moderately high temperatures, etc.	Low temperatures, etc.

It sometimes happens that an influence acts as an accelerator at one point and inhibitor at another. Increase in temperature, for example, speeds up the solution of the iron, but retards the removal of the hydrogen by cutting down the concentration of the dissolved oxygen. High purity in the iron increases its tendency to dissolve, but its high overvoltage hinders the formation of diatomic hydrogen.

One of the most interesting inferences to be drawn from the electrochemical theory is that anions have no part in corrosion except in special cases, as the production of passivity by chromates, etc. Their only possible activity is to affect the concentration of the Fe^{++} of the solution, either by precipitation, the formation of soluble compounds of low ionization, etc. Chloride ions, it will be remembered, have a way of forming salts of somewhat reduced ionization, and this may explain the increased corrosive effects attributed to them. Chemists are not all agreed on this point, but without doubt the influence of anions is far less than formerly thought.

One of the most satisfying aspects of the electrochemical theory is its explanation of the action of rust and similar deposits. As stated above, corrosion occurs, not where the oxygen comes in contact with the metal, but at some point slightly distant. Professor Evans' experiment showed that corrosion takes place, not where the oxygen concentration is greatest, but where it is smallest. The corrosive effect of rust lies in the fact that it is hydroscopic and saturates itself with the solution, so that the iron beneath is in electrical contact with the liquid. It serves as a shield to prevent access of oxygen, so that oxygen concentration cells are set up, iron corroding under the rust while H^+ ions are discharged and oxidized to water on the exposed metal. It will be seen that the consequence of such action is pitting and eventually perforation. Many other

hydroscopic solids behave like rust in this respect. The spreading of rust is due to low oxygen concentration at the edge of a rust patch, due in a large degree to the consumption of oxygen in oxidizing $Fe(OH)_2$ to $Fe(OH)_3$. The creeping of rust under certain metallic platings as tin is similarly explained. Iron oxide has a volume several times the volume of the original iron, so that rust formation acts as a wedge to pry the plate loose, and corrosion proceeds in the non-aerated pockets. R. J. McKay of the International Nickel Company, New York City, has studied this effect of oxygen concentration cells on corrosion, and has shown that inequalities in aeration may be a considerable factor in corrosion.

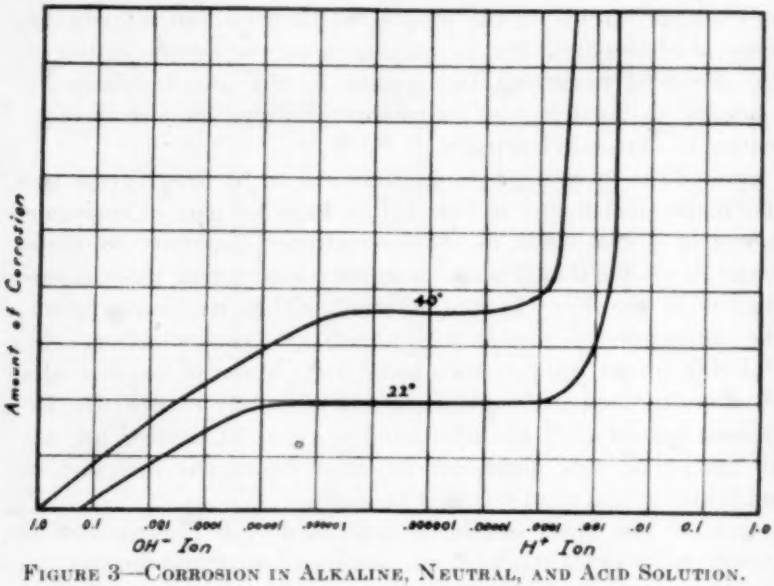


FIGURE 3—CORROSION IN ALKALINE, NEUTRAL, AND ACID SOLUTION.

This electrochemical mechanism of corrosion makes intelligible the otherwise anomalous results obtained by Whitman, Russell, and Altieri at the Massachusetts Institute of Technology. They measured the speed of corrosion of iron at 22 degrees and 40 degrees in a number of solutions ranging from 1.0 N OH^--ion concentration to .01 N H^+-ion concentration, maintaining the concentration of dissolved oxygen as constant as possible. Upon plotting their results the curves shown in figure 3 were obtained. For alkaline solutions, ranging from 1.0 N to 0.0001 N, the speed of corrosion depends on the concentration of H^+ (or OH^-) only. For approximately neutra solutions, the speed of corrosion is independent of the H^+-ion concentration, and dependent only

on the concentration of the dissolved oxygen. When an acidity of about .0001 N is reached, corrosion increases very rapidly and the speed depends mainly on the sample of metal used. It has been pointed out earlier in this paper that in corrosion we are dealing with consecutive reactions. Following the well-known rule for such cases, the total action cannot proceed any faster than the slowest step. For alkaline solutions, equation (1), page 413, is the slowest step, and its speed is determined by the concentration of the H^+-ions. In neutral solutions the speed of corrosion is limited by the rate at which the dissolved oxygen diffuses up to the metal to oxidize the atomic hydrogen (equation (2b)). In acid solutions, equation (2a) sets the pace, and in this reaction the speed of transformation of atomic into ordinary hydrogen is controlled by overvoltage effects.

The final question is, if the electrochemical theory diagnoses the malady of corrosion properly, what treatment does it suggest to prevent or reduce its bad results? This theory tells us that the tendency to corrode is an inherent property of iron; as long as iron is iron it will tend to change to rust just as surely as it comes in contact with the instruments of corrosion, oxygen and moisture. From the standpoint of thermodynamics, iron of the highest purity—wrought iron, for example—should be the most corrodible form of iron, since it has the highest ionization tension. This corrosion may be held in check for a while because of the absence of impurities of lower overvoltage to serve as cathodes for the discharge of H^+ ions. But sooner or later, the proper catalysts for corrosion are going to appear in the form of a speck of rust or contact with a dissimilar metal, and pure iron will succumb to the "grim destroyer" rust just like the cheaper forms. The best defense against rust is just what engineers have been doing in the past, and the theory fully justifies their procedure. There are only two ways to prevent corrosion: First, changing the properties of the iron, and second, insulating the iron from the corrosive medium. The first method involves alloying with ennobling ingredients, and the second covering with protective layers like paint, Fe_3O_4, and metallic films. Alloying the iron holds out little hope, owing either to a deterioration of the mechanical properties of the metal, or because of excessive cost. A fairly high silicon content inhibits corrosion, but a brittle metal like duriron is unthinkable as a substitute for steel. The small percentages of alloying ingredients sometimes suggested do not repress the ionization

tension of the iron enough to make them efficient. Probably they would have to be added in amounts of more than ten per cent to make them worth while. It is likely that engineers will continue to cover their steel with paints, or alloy them superficially with zinc and aluminum, or coat them with a hard blue layer of magnetic oxide.

CAN WE PREDICT EARTHQUAKES?

By Dr. Bailey Willis,

Professor Emeritus of Geology, Stanford University.

(This is an unsensational statement on the earthquake problem by one of America's leading seismologists. Is there danger of earthquake in California, New England, and elsewhere in the United States? Dr. Willis states the facts and the reader can draw his own conclusions.)

"All I know is what I read in newspapers," as Will Rogers says. At least that is true as regards "predicting" earthquakes. Prediction connotes precision and precision spices news. Hence news predicts precisely. There will be a destructive earthquake shock in Wall Street in two years, two months, and a day. That, telegraphed by an irresponsible reporter is news, though not true. There have been severe earthquake shocks in New England. They are sure to occur again sooner or later. Common sense demands that we take precautions against disaster. That is not news, though true.

Earthquake news, served up as a kind of side dish, is overspiced. It is time for seismologists to give the public plain food. Certain facts we know; others we think we know; still others we infer confidently; others doubtfully; then we guess. The prediction of an earthquake is a guess, which I prefer to call a forecast.

We know that earthquakes are natural phenomena, which have occurred from time to time, at longer or shorter intervals, with greater or less violence, but unequally as regards time-intervals and intensities in different countries.

If earthquakes were like comets they would return at definite intervals. But they do not resemble comets in any respect whatever. Rather are they like storms, an effect of concentrated energy; gathered in the one case in the air and reaching a crisis at frequent intervals; in the other case gathered in the earth's crust and rising to a critical state at longer intervals. That much we know regarding their periodicity and we can say with confidence that the farther we are from the last great shock, the nearer we are to the next one.

We know that sometimes, but not always, earthquakes group themselves in a district in a brief sequence of years. We recognize in those cases what we call fore-shocks, a relieving shock, and after-shocks. When we have a full series there is no difficulty in distinguishing the several parts of the sequence. The foreshocks are moderately severe and limited in their effects to a small area. The relieving shock is one of great intensity and large area. The after-shocks gradually diminish in intensity and frequency. In case of a moderately severe earthquake, however, such as the Santa Barbara incident, we cannot know definitely to what extent it may have served as a relieving shock for that locality or in what manner it may have relieved adjacent districts of strain, or have increased the strain upon them. Here we begin to guess.

We may be guided in guessing by related facts and may feel more or less justified accordingly. Thus the historical record shows that southern California is a province which has been shaken from time to time by earthquakes of a general character. In 1857 the disturbance was strong over an area of some 250,000 square miles. That is, it compared in extent with the earthquake of February 28, 1925, in the eastern States, but it was much more violent. The Santa Barbara shock, by contrast, shook an area that did not exceed 3000 square miles and points of high intensity were curiously limited and sporadic. The energy released in the latter case was not more than one percent, very likely not one tenth of one percent of that set free in 1857. The 1857 shock was a relieving shock. It was followed by a long interval of quiet. I would not feel safe in guessing that the Santa Barbara incident would have a like effect.

During the last seven years there have been four incidents of the Santa Barbara kind in southern California. We do not know that they are fore-shocks. We cannot know until the relieving shock shall have shown that they are. But we are on the safe side in guessing that they will prove to have been fore-shocks.

We think we know that earthquakes are produced by pressure which distorts the elastic rocks, so that when they slip they vibrate. It has been found by the Coast Survey that the mountains in California are on the move, so to speak; that is, they are pushed out of place, and we connect their movements with the pressure to which we attribute earthquakes. In southern California certain mountain peaks not far from Santa Barbara have moved northward, in the direction in which the earthquake pressure should push them, as we understand it. In northern California other mountain peaks moved northward until after the earthquake of 1906, but they then began to slide back southward. The shock of 1906 was a relieving shock for the north and we guess that it took off the pressure. The mountains in the south have not begun to slide back, so we think that the pressure has not been relieved, and this confirms our guess that the relieving shock is ahead of us.

Until recently we have had to depend upon our senses for evidence of nearby earthquake activity and we have been aware that their capacity to detect vibrations is limited to the greater ones. Thousands of minor shocks or micro-tremors occur daily and they should give us an index of the elastic strain in the rocks not unlike the significance of a barometer in weather observations, if we could but register them constantly. We have had instruments, it is true, that would record the occurrence of a great shock a thousand miles away, but they are not tuned to the more rapid waves of a local tremor. Through the researches of the Carnegie Institution of Washington, we now have available the Wood-Anderson seismometer, a simple, but very sensitive little instrument, which can be tuned to record elastic waves of any length, and we are thus in a position to know what the actual condition of the earthquake strain is in any district where the seismometers may be installed. We shall then guess more certainly, but we have to wait until the value of that information is appreciated in San Francisco, New York, Boston, and elsewhere, at least to the degree that business interests will provide the instruments as a measure of self-protection.

In the meantime the seismometers have been made and tested at Pasadena, where they have proved their efficiency by registering as many as two hundred micro-tremors a year. This state of activity is not what we would expect during a period of quiet. It might occur before a relieving shock or soon after one, but in the latter case the great shock must have occurred recently, and that is not the fact.

To sum up for southern California: Sixty-eight years have passed since the last general earthquake; severe strain is indicated by local shocks, displacements of mountains, and seismometric records; in 1852 a disturbance similar to that of 1925 preceded the relieving earthquake of 1857. Will history repeat?

For northern California the facts are: It is only 16 years since the greatest relieving shock recorded in that province; slight, though sensible tremors occur from time to time; they are not as strong as we would expect fore-shocks to be; the pressure which moved mountains has been relaxed. The best guess seems to be that the strain has begun to re-accumulate, but is not likely to reach a critical condition for two or three decades.

As regards New England we know that the conditions are very different from those in California. Intervals between relieving shocks are much longer; distinct fore-shocks have not been recognized; movements of mountain peaks may have occurred, but are unknown; seismometric records of micro-tremors are lacking. The St. Lawrence earthquake of February 28, 1925, no doubt relieved the strain within a considerable area. Does that area include New England? I do not know. Does it include New York? I cannot guess! The poverty of information is lamentable. We face two possibilities, as far apart as the poles: (1) the strain is relieved; we need not expect another severe shock in a century or two. Or (2) the strain is not relieved; it has been increased by the failure of one part of the continental structure, which brings the pressure to bear on another; if so, we may expect renewed activity soon. No light leads in either direction.

New York, Philadelphia, Washington are in a seismic belt where shocks have been so rare and so slight that we hardly expect them. It may be a safe guess that no earthquake of any severity will ever affect those cities. And yet—there was the Charleston earthquake of 1886! A great shock, its intrusion upon our fancied security gives one pause. I wish seismometers had been longer in use, that they were more generally installed today.—Science Service.

WOMEN'S FINGERS WORK FASTER THAN MEN'S.

A method of measuring the speed in an individual's fingers has been devised. The test has been applied to 1,021 women applying for work in the shops of an electrical company and the results are described in a recent issue of the Journal of Personnel Research by Mildred Hines and Johnson O'Connor.

The equipment used by the experimenters consisted of nothing more than 300 brass pins and a flat metal plate in which 100 holes were drilled part way through. Candidates for work requiring agile fingers are asked to pick the pins from a tray in which they are piled loosely and to place three pins in each drilled hole in the plate as rapidly as possible. They are instructed to try to pick up the pins three at a time in order to make maximum speed. Individuals vary widely in this test. The fastest finish in less than six minutes and the slowest require from twelve to fifteen minutes.

Since the inauguration of this test seventy-seven new women workers have been assigned to the fine meter or instrument work requiring finger dexterity. Subsequent records show that more than 85 per cent of these women are successful in the work. The test also showed that women are much better adapted for this work than are men.

The test is said to eliminate much of the guess work and personal equation factor in the hiring of workers for this type of work.—*Science Service.*

A NEW FORM OF "CENTRIFUGAL FORCE" APPARATUS FOR THE STUDY OF ROTATIONAL FORCES.

By Paul E. Klopsteg,[1]

Central Scientific Co., 460 E. Ohio St., Chicago.

Nearly everyone who has taken a course in college laboratory physics is familiar with the so-called centrifugal force apparatus described in Millikan's and some other manuals (Cenco No. F1053). In this apparatus a large cylindrical weight with its axis vertical is held between two stops on a square vertical shaft. The square shaft terminates in a spindle which fits the standard rotator socket. Two light cords, secured to the upper side of this weight, pass upward over two small pulleys and thence outward along two sets of symmetrical horizontal rods, and their outer ends are secured in a pair of equal small masses. These masses are free to slide on the supporting rods. At the prope speed the large weight theoretically balances the centrifuga' reaction of the small masses.

A serious fault in this apparatus, which users may have discovered, but which seems to be not generally recognized, is the fact that the equilibrium between the centripetal and centrifugal forces is unstable. The instability results from the fact that the centripetal force supplied by the large weight is constant whereas the centrifugal reaction of the small masses increases with increasing radius. Consequently when the speed of the apparatus has reached the point at which the large weight is pulled from its lower support, no matter how small the displacement, the radius of rotation of the small masses increases by the same amount, their centrifugal reaction is increased, and without further change in speed, they move outward until the large weight strikes the upper stop. Reduction of the speed to the point at which the weight begins to descend results in the reverse process—the large weight moves all the way to its lower stop. Sometimes it is possible to hold the large weight in equilibrium between the two stops, but this is obviously the result of friction producing the stabilizing effect. If sufficient friction is present to produce the desired stability, close agreement between experimental values of centrifugal force and the measured centripetal force cannot be expected, and much less attained.

An apparatus in which the faults above described are eliminated must provide for a centripetal force which at suitable operating speeds will be in a stable equilibrium with the cen-

[1] In charge of Development and Manufacturing, Central Scientific Co.

To sum up for southern California: Sixty-eight years have passed since the last general earthquake; severe strain is indicated by local shocks, displacements of mountains, and seismometric records; in 1852 a disturbance similar to that of 1925 preceded the relieving earthquake of 1857. Will history repeat?

For northern California the facts are: It is only 16 years since the greatest relieving shock recorded in that province; slight, though sensible tremors occur from time to time; they are not as strong as we would expect fore-shocks to be; the pressure which moved mountains has been relaxed. The best guess seems to be that the strain has begun to re-accumulate, but is not likely to reach a critical condition for two or three decades.

As regards New England we know that the conditions are very different from those in California. Intervals between relieving shocks are much longer; distinct fore-shocks have not been recognized; movements of mountain peaks may have occurred, but are unknown; seismometric records of micro-tremors are lacking. The St. Lawrence earthquake of February 28, 1925, no doubt relieved the strain within a considerable area. Does that area include New England? I do not know. Does it include New York? I cannot guess! The poverty of information is lamentable. We face two possibilities, as far apart as the poles: (1) the strain is relieved; we need not expect another severe shock in a century or two. Or (2) the strain is not relieved; it has been increased by the failure of one part of the continental structure, which brings the pressure to bear on another; if so, we may expect renewed activity soon. No light leads in either direction.

New York, Philadelphia, Washington are in a seismic belt where shocks have been so rare and so slight that we hardly expect them. It may be a safe guess that no earthquake of any severity will ever affect those cities. And yet—there was the Charleston earthquake of 1886! A great shock, its intrusion upon our fancied security gives one pause. I wish seismometers had been longer in use, that they were more generally installed today.—Science Service.

WOMEN'S FINGERS WORK FASTER THAN MEN'S.

A method of measuring the speed in an individual's fingers has been devised. The test has been applied to 1,021 women applying for work in the shops of an electrical company and the results are described in a recent issue of the Journal of Personnel Research by Mildred Hines and Johnson O'Connor.

The equipment used by the experimenters consisted of nothing more than 300 brass pins and a flat metal plate in which 100 holes were drilled part way through. Candidates for work requiring agile fingers are asked to pick the pins from a tray in which they are piled loosely and to place three pins in each drilled hole in the plate as rapidly as possible. They are instructed to try to pick up the pins three at a time in order to make maximum speed. Individuals vary widely in this test. The fastest finish in less than six minutes and the slowest require from twelve to fifteen minutes.

Since the inauguration of this test seventy-seven new women workers have been assigned to the fine meter or instrument work requiring finger dexterity. Subsequent records show that more than 85 per cent of these women are successful in the work. The test also showed that women are much better adapted for this work than are men.

The test is said to eliminate much of the guess work and personal equation factor in the hiring of workers for this type of work.—*Science Service.*

A NEW FORM OF "CENTRIFUGAL FORCE" APPARATUS FOR THE STUDY OF ROTATIONAL FORCES.

By Paul E. Klopsteg,[1]

Central Scientific Co., 460 E. Ohio St., Chicago.

Nearly everyone who has taken a course in college laboratory physics is familiar with the so-called centrifugal force apparatus described in Millikan's and some other manuals (Cenco No. F1053). In this apparatus a large cylindrical weight with its axis vertical is held between two stops on a square vertical shaft. The square shaft terminates in a spindle which fits the standard rotator socket. Two light cords, secured to the upper side of this weight, pass upward over two small pulleys and thence outward along two sets of symmetrical horizontal rods, and their outer ends are secured in a pair of equal small masses. These masses are free to slide on the supporting rods. At the prope speed the large weight theoretically balances the centrifugal reaction of the small masses.

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An apparatus in which the faults above described are eliminated must provide for a centripetal force which at suitable operating speeds will be in a stable equilibrium with the cen-

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trifugal force but with the important provision that friction must not do the stabilizing. At the same time, the stability must not be so great as to result in diminished sensitiveness of the apparatus to small changes in speed.

The first requirement mentioned is met in an apparatus devised by Professor Richards of the University of Pennsylvania and modified by Professor Ingersoll of the University of Wisconsin. The apparatus is described in experiment 18 of Ingersoll's manual (1925). In this apparatus a helical tension spring provides a centripetal force which increases as the radius of the path of the rotated body increases. A short stiff spring is used which results in greater stability than might be desired; however, the apparatus is a decided improvement over the form first described.

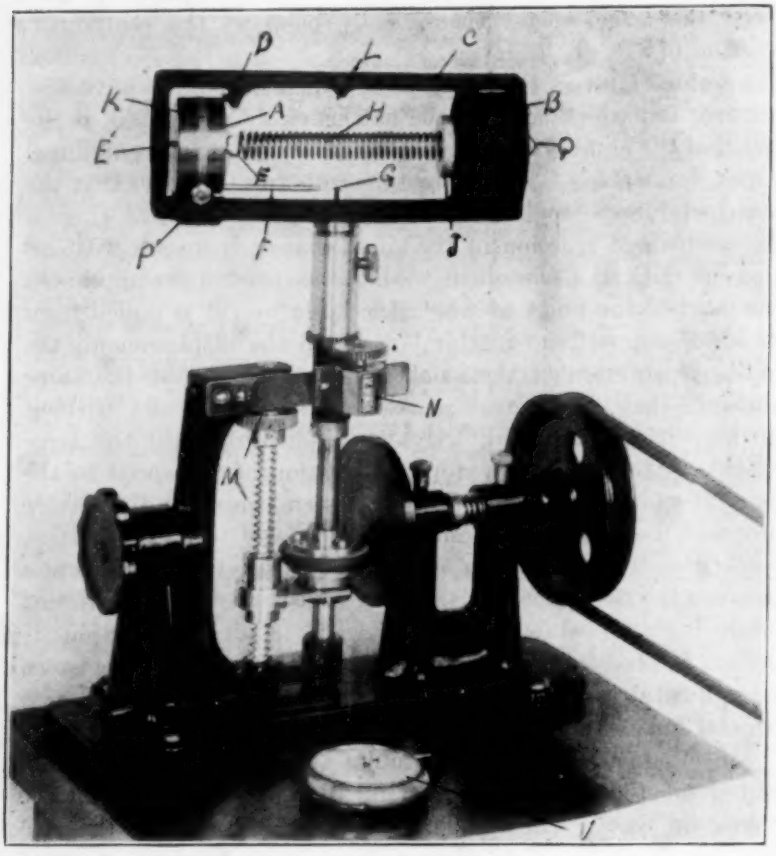

FIGURE 1—WALKER'S EXPERIMENT.

The apparatus shown in figures 1 and 2 resulted from a detailed study of the various desirable and undesirable features in a centrifugal force apparatus, from the points of view both of good pedagogy and of economical manufacturing. It has been designated the Cenco Centrifugal Force Apparatus. Experiments with it have demonstrated very satisfactory per-

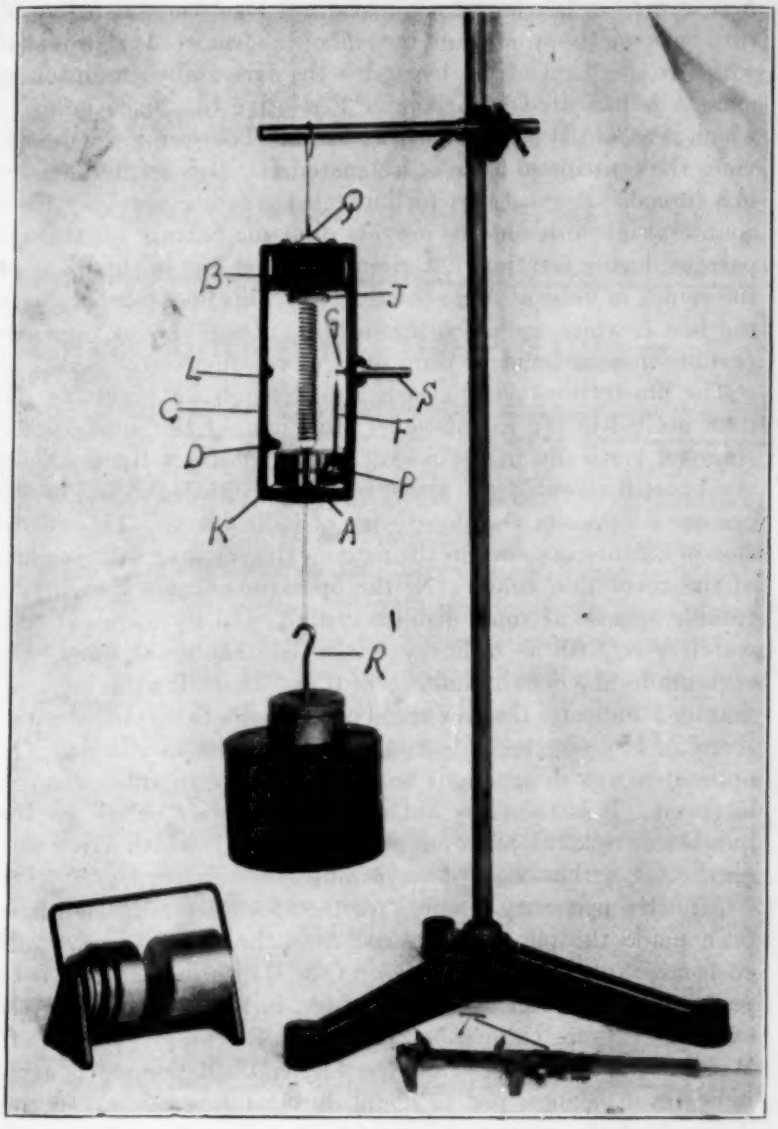

FIGURE 2—A DIAGRAMMATIC REPRESENTATION OF THE MECHANISM OF CORROSION.

formance, simplicity of manipulation, and excellent agreement between the calculated and measured values of the forces.

The apparatus as shown in figures 1 and 2 is mounted in a light aluminum frame C approximately 6 by 15 cm. The frame is provided with a spindle S which fits the standard chuck of the friction drive rotator shown in figure 1. The cylindrical mass A is secured in horizontal pivot bearings P in which it is free to turn between the stop D and the end of the frame. It is provided with two small eyes E,E′, located in the axis, and the position of mass A is indicated by a pointer F relative to a fixed index G which is mounted in the axis of rotation. The spring which provides the centripetal force is designated H. It is secured axially in a threaded sleeve J by which its tension can be varied. B is a counterweight intended to provide dynamic balance for the apparatus during rotation. A circumferential line in the plane of the center of mass of A is shown at K. This line, together with the line L which indicates the location of the axis of rotation, permits measurement of the radius of rotation.

The illustrations show clearly the methods for obtaining the data needed in the calculations. In Figure 1 the apparatus is clamped vertically in the socket of the rotator. By means of the knurled screw M the speed is adjusted until the end of the pointer is opposite the sharp edge of indicator G. This condition of balance is shown in the figure. Having noted the reading of the revolution counter N, the operator engages it with the rotator spindle at some definite instant, and by means of stop watch V or with an ordinary watch determines the number of revolutions in a definite interval of time. If, during this interval, pointer F indicates that the speed of the motor is varying slightly, screw M is turned so as to compensate for the variations. The apparatus was designed to be very sensitive to small changes in speed. It is therefore not difficult to obtain values for the number of revolutions in one minute intervals which agree with each other within one or two revolutions.

After the necessary readings for the speed determination have been made the piece is removed from the rotator socket and suspended from a hook by stirrup Q as shown in Fig. 2. A wire paper clip, or better still, a fine wire, is threaded through the eyelet E′ (Figure 1) and a weight carrier R is suspended from it. Weights are then placed on the carrier until pointer F again indicates a balance, just as it did during the rotation. Having determined the amount of weight (including that of mass A)

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OAKLAND TEACHERS PREPARING FOR INSTRUCTION BY RADIO.

Lessons in the technique of radio sending and receiving were given this fall to 20 teachers of Oakland, Calif., selected to give classroom instruction by radio. The class was under the direction of the assistant director of the bureau of curriculum development, research, and guidance of the Oakland public schools. Details considered in connection with radio-lesson preparation were how to talk before a microphone and how to give lessons to 10 different schools tuned in, followed by a sketch of the school work outlined for the first semester. It is believed that the lessons by radio will not only benefit the children, but will convey valuable ideas to teachers in the preparation of their own lessons.—School Life.

necessary to pull the spring to the point of balance, the radius of rotation is measured by means of the vernier caliper T between lines K and L. It may be observed at this point that by suspending the apparatus and weights in the manner shown the axis of the spring will automatically be vertical, which is a necessary condition for accuracy in measuring directly the pull of the spring.

Without going into much detail about the process by which the final design was evolved, it may be mentioned that the relation between the mass M of A and the constant (grams force per cm elongation) of the spring was so predetermined that at the maximum speed of rotation the apparatus is *just stable*. This condition of almost critical stability is attained if the design of the spring provides that the increase in force exerted by the spring would be very slightly greater than the increase in centrifugal force of the mass M if the radius were increased by a small amount. If the speed chosen as the basis for the design is appreciably exceeded, the mass will move outward and rest against the fame. If it were perfectly free to move it would continue outward indefinitely at a definite speed somewhat greater than the "critical" speed. The lower the speed, the greater the stability. As mentioned in the description, adjustment for the tension in the spring has been provided so that the apparatus may be used at a number of different speeds; but the apparatus is most sensitive to speed variations at maximum tension of the spring.

The data required for the final computation are M, the mass of the body A; v, the linear speed of its center of mass; r, its radius of rotation; and F, the force, obtained as shown in figure 2, which exerts the same pull on the spring as did the mass A during the rotation. In the model on which the experiments were performed M was approximately 200 g, v about 320 cm per second, corresponding to about 540 r. p. m.; r about 5.7 cm and F about 3700 grams of force. The above data for v and F correspond to maximum tension of the spring.

It was found in the experiments that the mass of the spring itself is not negligible, since during rotation the centrifugal force due to this mass is responsible for a very slight elongation of the spring. This in effect results in a balance being obtained at lower speed than would be necessary if the spring did not elongate because of its own mass; hence the calculated value of the force

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is slightly smaller than it should be. Analysis shows that if the spring is symmetrical with reference to the axis of rotation the additive correction amounts to $\frac{mv^2}{3r}$ in dynes, where m is the mass of the spring; its length is approximately $2r$. The formula thus becomes $F=(M+\frac{m}{3})\frac{v^2}{r}$. This question will be discussed in detail in a publication elsewhere.

Table 1 is a summary of data and results obtained in a series of three experiments performed with three different values of the spring tension. A comparison of the respective values in the last two lines shows that agreement in calculated and observed values of the forces within $\pm 1\%$ may be expected. In the hands of the student in the laboratory the limits of agreement will probably be somewhat wider than this, but even 2% is much better than the results obtainable with the older form of apparatus first described.

	Exp. 1 Maximum tension of spring	Exp. 2 Medium tension of spring	Exp. 3 Minimum tension of spring	Remarks
M (rotating mass), g	196.4	196.4	195.5	A change in M was made between Exps. 2 and 3
r (radius, axis to center of mass) cm	5.70	5.69	5.69	Average values of 3 measurements in each case
m (mass of spring), g	12.0	12.0	12.0	
l (length of extended spring) cm	9.4	8.7	8.2	
F_c (computed from $(M+\frac{m}{3})\frac{r^2}{rg}$, g	3740	3080	2730	Last figure rounded
Observed F_s, centripetal force exerted by spring, g	3760	3090	2700	Apparatus sensitive to ± 10 grams.

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All readers are invited to propose problems and to solve problems here proposed. Drawings to illustrate the problems should be well done in India ink. Problems and solutions will be credited to their authors. Each solution or proposed problem, sent to the Editor, should have the author's name introducing the problem or solution *as on the following pages.*

The Editor of the department desires to serve its readers by making it interesting and helpful to them. Address suggestions and problems to C. N. Mills, Illinois State Normal University, Normal, Ill.

SOLUTION OF PROBLEMS.

893. *Proposed by A. S. Haynes, Bangatore, S. India*

Inscribe the maximum rectangle in a given sector of a circle.

Solved by Michael Goldberg, Philadelphia, Pa.

In the solutions appearing in the January, 1926, issue Mr. George Sergent and Philomathe assume symmetry. A further consideration shows that the results given by them are not correct for all the values of the central angles. For all angles of the sector less than 90° the rectangle, shown in figure 1, is larger than the rectangle shown in figure 2. A further study shows that the method of figure 3 gives a greater area than figure 2 for angles up to 106° 15′, and for angles greater than 106° 15′ the method of figure 2 is correct. When $x = \frac{1}{4}a$ the constructions fail in more than half of the cases.

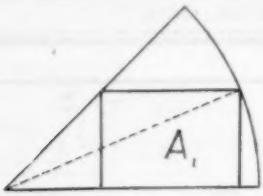


FIG. 1

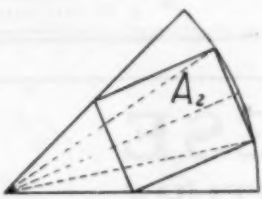
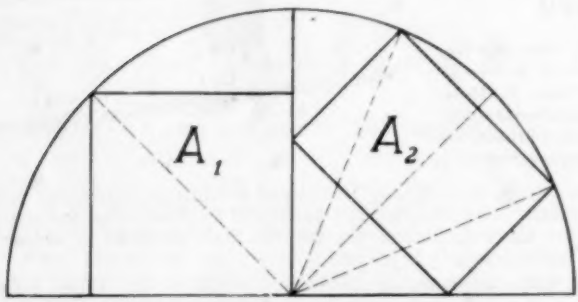


FIG. 2

FIG. 3



906. *Proposed by B. F. John, La Salle College, Philadelphia, Pa.*

A block of marble weighing 40 pounds is divided into four parts such that all integral number of pounds between one and forty may be weighed. Find the weight of each part.

Solution by Leonard Carlitz, Philadelphia, Pa.

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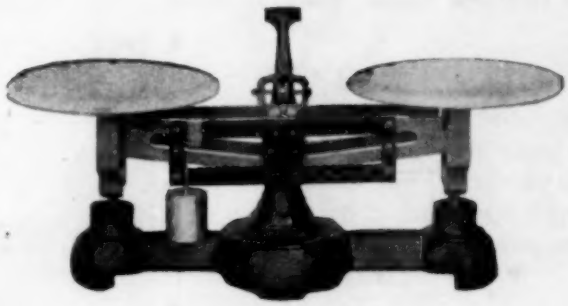

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The problem is equivalent to finding the solution of

$$k = ax + by + cz + dw, \qquad (1)$$

where $k = 1, 2, 3, \ldots\ldots 40$; $a, b, c, d = -1, 0, 1$.

Now if the number N be expressed in the scale of 3,

$$N = a_0 + a_1.3 + a_2.3^2 + \ldots\ldots + a_n.3^n.$$

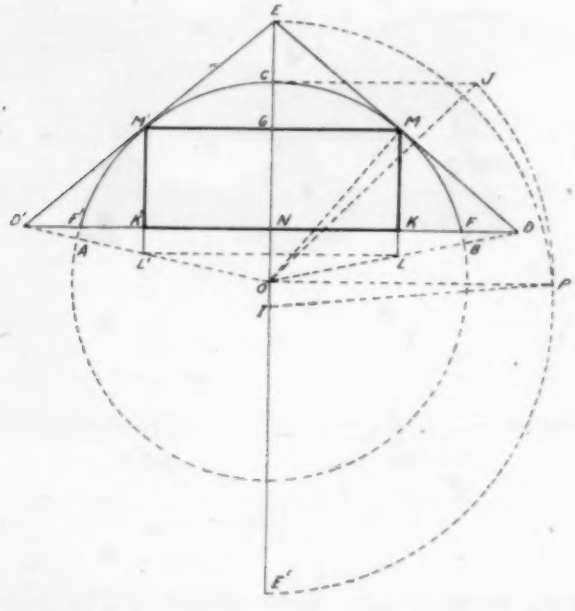
Hence, noticing that $40 = 1 + 3 + 3^2 + 3^3$, it follows that a solution of (1) is $x = 1$, $y = 3$, $z = 9$, and $w = 27$. Therefore, the required weights are 1, 3, 9, and 27 pounds.

Also solved by *P. H. Nygaard, Spokane, Wash.; Michael Goldberg, Tillie Dantowitz, Philadelphia, Pa.; Norman Anning, Ann Arbor, Mich.; Albert L. Johnson, Ann Arbor, Mich.; Johannes Witt, Moukden, Manchuria.*

907. *Suggested by 893. Proposed by Philomathe, Montreal, Can.*

Inscribe the maximum rectangle in a given segment of a circle.

I. *Solved by George Sergent, Tampico, Mexico.*



Let FCF′ be the given segment of a circle O, subtended by the chord FF′, and OC the radius bisecting the segment. For the analysis the figure and the solution of problem 893 may be used. If DD′ is drawn, we see that the maximum rectangle inscribed in the given segment is the difference between the maximum rectangle inscribed in the sector OACB and the maximum rectangle inscribed in the triangle DOD′. This difference is the maximum rectangle inscribed in the isosceles triangle DED′.

Then we have first to determine this triangle, or its half, the right triangle DNE, or, in other words, to draw between the given chord and the radius perpendicular to it a tangent such that its mid-point is the point of contact. The problem will be solved if $OE = OD = OD' = x$ can be determined. Let $ON = d$, and r be the radius. Deriving the equation $x^2 + dx - 2r^2 = 0$, we find that

$$x = -\tfrac{1}{2}d \pm \sqrt{\frac{d^2}{4} + 2r^2}.$$

Construction. On the diameter perpendicular to the chord of the given segment lay off from the center $OI = d/2$, on the side opposite the segment. On OI as a side construct the right triangle IOP, such that

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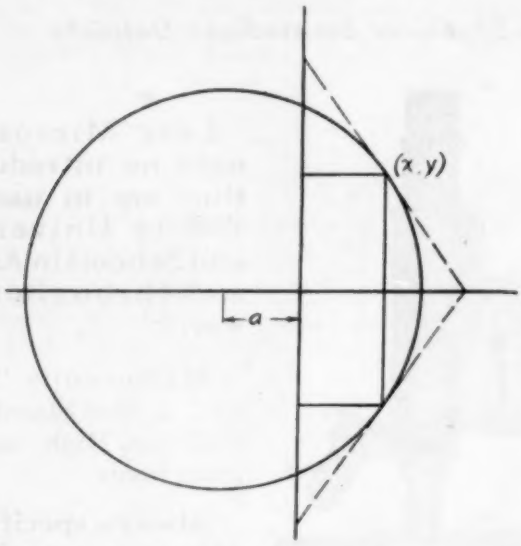
$OP = r\sqrt{2}$. The hypotenuse of this triangle is $\sqrt{\frac{d^2}{4}+2r^2}$. From I as a center and IP as a radius draw an arc of a circle, interseeting the diameter at E, on the side of the segment. Then

$$OE = -\tfrac{1}{2}d \pm \sqrt{\frac{d^2}{4}+2r^2}.$$

Determine the points of contact M and M′ of the tangents drawn from E to the segment. Drawn MM′ and the perpendiculars MK and MK′ to the given chord. MM′K′K is the required rectangle.

II. *Solved by Michael Goldberg, Philadelphia, Pa.*



Editor. This solution gives the computation to determine the construction.

Take the axis of the segment and its base as coordinate axes. The equation of the circle may be written

$$(x+a)^2+y^2=r^2.$$

The area of the rectangle is

$$A = 2xy = 2x\sqrt{r^2-(x+a)^2}.$$

Setting $dA/dx = 0$, and solving gives

$$x = \frac{-3a \pm \sqrt{a^2+8r^2}}{4}.$$

When the arc of the segment exceeds three right angles, the maximum rectangle is the inscribed square.

The length of the tangent at (x, y) intercepted by the axes is bisected at (x, y). The inscribed rectangle is the maximum inscriptible in the triangle formed by this tangent and the axes.

Also solved by *Leonard Carlitz, Philadelphia, Pa.; R. T. McGregor Elk Grove, Cal.; Orville Barcus, Columbus, Ohio; Johannes Witt, Moukden, Manchuria.*

908. *Proposed by P. H. Nygaard, Spokane, Wash.*

What must be the characteristic properties of $f(x)$ such that the mean of the roots of $f(x)$ is the same as the mean of $f'(x)$?

Solved by Michael Goldberg, Philadelphia, Pa.

Any function which may be written in the form

$$f(x) = x^n + a_1x^{n-1} + a_2x^{n-2} + \ldots + a_kx^{n-k} \ldots + a_n = 0$$

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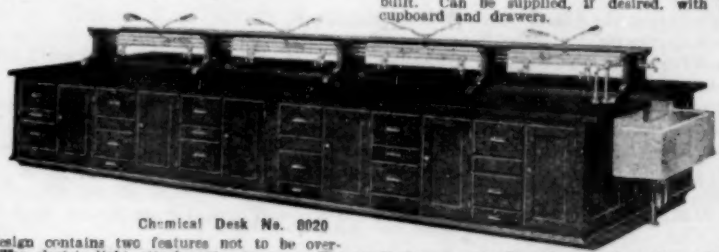

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obeys the given condition. Since a_1 is the sum of the n roots, the mean is a_1/n.

$f'(x) = nx^{n-1} + (n-1)x^{n-2} + \ldots + a_{n-1} = 0.$

Since there are only $(n-1)$ roots and their sum is $(n-1)a_1/n$, the mean is

$$\frac{(n-1)a_1}{n(n-1)} = \frac{a_1}{n}.$$

Also solved by *Leonard Carlitz, Philadelphia, Pa.;* and the *Proposer.*

909. *Proposed by Norman Anning, Ann Arbor, Mich.; Johannes Witt, Moukden, Manchuria.*

Describe the circle with center at O (0, 0), which passes through the point P (8, 7). Draw a tangent at P to this circle and on it lay off PQ equal to the distance from (0, 11) to (11,0). Show that the area of the square on OQ is very nearly equal to the area of the circle. Show also how to continue the construction in order to make it yield an approximation to the circumference of the circle.

Solved by Tillie Dantowitz, Kensington H. S., Philadelphia, Pa.

$(OP)^2 = 8^2 + 7^2 = 113.$ $(PQ)^2 = 11^2 + 11^2 = 242.$ $(OQ)^2 = 355.$

If K represents the area of the circle, then

$$K = \pi R^2 = (3.1416)\,.113 = 355.0008.$$

Hence the square on OQ is approximately equal to the area of the circle.

The next problem is to find a point on PQ (Q′) so that the perimeter should be approximately equal to the circumference of the circle. In the triangle POQ′ denote PQ′ by x, and angle POQ′ by A. Then $x = \sqrt{113}$ tanA The perimeter of POQ′ is

$$\sqrt{113}\ (1 + \tan A + \sec A).$$

Assume that the perimeter of POQ′ equals to the circumference of the circle, then

$$\sqrt{113}\ (1 + \tan A + \sec A) = (6.2832)\sqrt{113}.$$

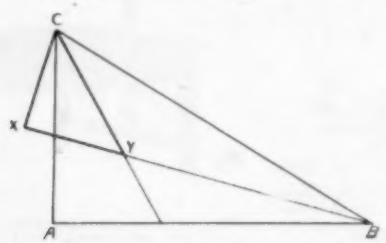
Solving this equation we find that $A = 68°\ 34'$. Hence, when the angle POQ′ is nearly $68°\ 34'$, the construction is approximate.

Also solved by *Michael Goldberg, Philadelphia, Pa.; T. E. N. Eaton, Redlands, Cal.; Johannes Witt, Moukden, Manchuria.*

910. *For High Shcool Pupils. Proposed by the Editor.*

If three lines be drawn from the acute angles of a right angled triangle, two bisecting these angles, and the third a perpendicular to one of the bisecting lines, then the triangle included by these lines will be isosceles.

Solved by Oreal Lizarraga, Glendale, Ariz.



In the triangle ABC, $\angle ACB + \angle ABC = 90°$.

In the triangle BCY, $\angle BCY + \angle CBY = 45°$.

Therefore, $\angle CYX = 45°$. Likewise, $\angle XCY = 45°$.

Hence the triangle CXY is isosceles.

Also solved by *Naomi Penninger, Anita Walker, Glendale, Ariz.; Edward Crafts, Richard B. Kritch, Nesta Davies, Oak Park, Ill.; Paul Myers, Bellmore, Ind.; Tillie Dantowitz, Philadelphia, Pa.; Randall Sims, Albert Cook, Thelma Clinton, Arlie Bain, Thomas Rotramel, Benton Twp. H. S., Benton, Ill., Virginia Seidensticker, Chicago, Ill.; Preston Blair, Oliver Ebel, Harper Rowe, Martha Osterheert, Marian Ward, Velma Knox, Redlands, Cal.*

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PROBLEMS FOR SOLUTION.

921. *Proposed by R. T. McGregor, Elk Grove, Cal.*

The square on the third diagonal of a quadrilateral inscribed in a circle is equal to the sum of the squares of the tangents to the circle from its extremities.

922. *Proposed by J. E. B., Waco, Texas.*

Find the sum of the infinite series.

$$\frac{2}{1\cdot2\cdot3}\cdot\frac{1}{2}+\frac{10}{2\cdot3\cdot4}\cdot\frac{1}{2^2}+\frac{35}{3\cdot4\cdot5}\cdot\frac{1}{2^3}+\frac{102}{4\cdot5\cdot6}\cdot\frac{1}{2^4}+\frac{267}{5\cdot6\cdot7}\cdot\frac{1}{2^5}+\cdots;$$

923. *Selected.*

A and B are two fixed points on a circle whose center is O. P is any point on the circle, and perpendiculars PM, PN are drawn to OA, OB. Prove that the length of MN is constant.

924. *Proposed by Norman Anning, Ann Arbor, Mich.*

Break m^4-6m^2+1 into quadratic factors in three ways.

925. *For High Pupils. Proposed by J. F. Howard, San Antonio, Texas.*

If a circumscribed quadrilateral be formed by drawing tangents at the vertices of an inscribed quadrilateral the diagonals of the two quadrilaterals are concurrent.

ACTUAL RUBBER SHORTAGE SEEN FOR 1930.

The world's demand for crude rubber will exceed the supply by 37,000 tons in 1930 unless some plan of relief is adopted. This future shortage, which is actual, is troubling Congress almost as much now as the artificial shortage brought on by English restriction of rubber exportation which makes the price so high at present.

In hearings now being conducted by the Foreign and Interstate Commerce Committee of Congress to investigate the high price of rubber, Paul L. Palmerton, chief of the rubber division of the Department of Commerce, brought out that there were four methods by which Americans might combat the high prices caused by the present artificial shortage. One was a campaign for a more conservative use of what we have, making it last longer.

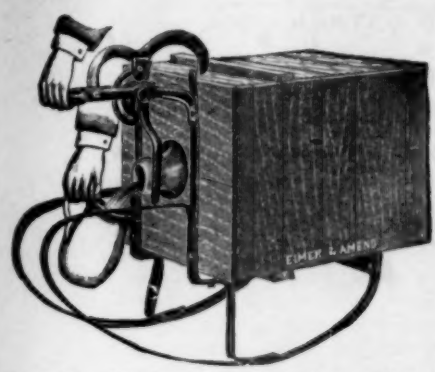
Substitutes were another possibility. Reclaimed rubber, although lacking some of the qualities of fresh natural rubber, could be mixed with new rubber in certain proportions for the manufacture of some articles wherein natural rubber had been used almost exclusively in the past.

In certain places, such as in the treads of tires, the use of reclaimed rubber decreased the durability. Tests on tire treads have shown that up to a certain point the durability is decreased regularly as the percentage of reclaimed rubber is increased.

Synthetic rubber has been unsuccessful commercially so far, although Germany, during the latter part of the war, was producing 150,000 kilograms of synthetic rubber per month. It is costly to produce and lacks elasticity, but it serves quite well in the manufacture of hard rubber products.

The stimulation of production of wild rubber in the Amazon Valley was another suggestion made by Mr. Palmerton, and the fourth was co-operative buying.

In view of the actual shortage which is prospective for us, he estimated that a million to a million and a half more acres of rubber need to be planted upon plantations of our own. Rubber trees do not begin to bear until 5 to 7 years old and full bearing is not obtained until 8 to 10 years old, so trees planted now cannot hope to affect the prospective shortage of 1930 but they can provide for the more distant future.—*Science Service.*



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WOMEN MAY BE INTELLECTUAL THOUGH MARRIED.

How may an educated woman live a normal life as wife and mother and at the same time maintain her intellectual activity, professional or otherwise? To aid in the solution of this question, Smith College, Northampton, Mass., has established an institute for the coordination of women's interests, to be financed for three years by the Laura Spelman Rockefeller Foundation. The study will be approached from two directions: How women may, by the elimination of wasteful occupations in the home, reduce to essentials the duties of home-keeping; and to discover methods of so modifying technical training for the professions that new subdivisions of professional work may be made which will be adapted to part-time employment of women or carried into the home without interference with normal home life.

BOOKS RECEIVED.

Adventures in Science, by William H. Cunningham, High School of Commerce, Boston, Mass. Pages v+221. 12½x17½ cm. Cloth, 1926. 72 cents. Ginn & Co., Boston.

America's Interest in World Peace, by Irving Fisher of Yale University. Pages x+123. 12x18 cm. Paper, 1926. Funk and Wagnalls, N. Y.

Life and Evolution, by S. J. Holmes of University of California. Pages v+449. 15x22½ cm. Cloth, 1926. $4.00. Harcourt Brace Co., 383 Madison Ave., N. Y.

BOOK REVIEWS.

Methods of Handling Test Scores, by Luella Cole Pressey and Sidney Leavitt Pressey, both of Ohio State University. Pages iv+60. 26x36 cm. Paper, 1926. World Book Co., N. Y. and Chicago. Price, $.60.

This is a brief and very elementary statement of what to do with test scores; how to tabulate them, how to find the median, how to use norms in comparing individuals and classes, and how to look for relationships between scores in different tests. Simple exercises are distributed throughout the text and answers to them are given.

W. N. Spurgin.

The Geometry of René Descartes. Translated from the French and Latin by David Eugene Smith and Marcia Latham, with a facsimile of the first edition 1637. Pages xiii+246. 18x24 cm. 1925. Open Court, Chicago. Price, $4.00.

La Géométrie of Descartes was written in French and afterwards translated into Latin by Van Schooten. Until the publication of the book under review there was no known translation into English. The translators and publishers are to be commended for their enterprise in making this work of Descartes easily accessible to students of the history of mathematics.

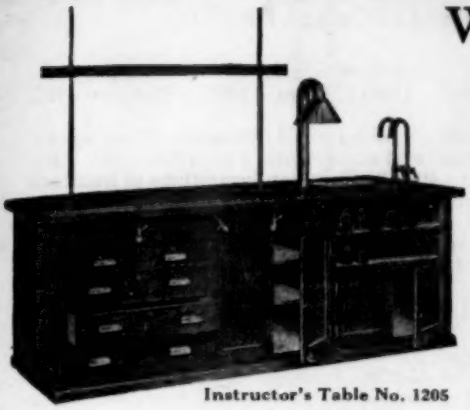
J. M. Kinney.

The Mechanical Investigators of Leonardo da Vinci, by Ivor B. Hart, Honorary Research Assistant in the Department of the History and Method of Science at University College, University of London. Pages vi+240. 16x23 cm. 1925. Open Court, Chicago. Price, $4.00.

Leonardo da Vinci, scientist, mathematician, engineer, painter, and sculptor, was one of the outstanding figures of the Renaissance. He published nothing but left a large number of note-books written in mirror script. These books have been deciphered and published, for the most part, in recent times.

In the volume under review the author presents a translation of the manuscript on "The Flight of Birds." This translation is preceded by 200 pages on the mechanical investigations of da Vinci. The book is a valuable contribution to the history of science.

J. M. Kinney.



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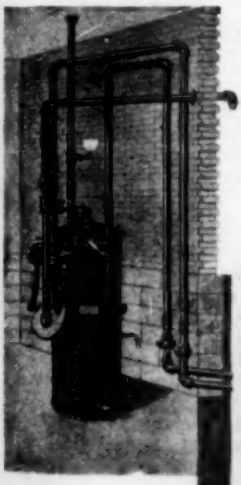

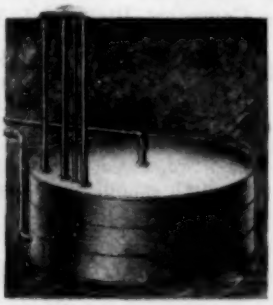

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Six-place Tables, by E. S. Allen, Associate Professor of Mathematics, Iowa State College. Pages xxiii+144. 10.8x17.7 cm. 1925. McGraw-Hill, New York. Price, $1.25.

This is a pocket edition of six-place tables of: (1) Squares, cubes, square roots, cube roots, circumferences, and areas from 1 to 1000. (2) Fifth roots and fifth powers from 0.1 to 40. (3) Common logarithms of numbers from 1000 to 10,000. (4) Common logarithms of sines, cosines, tangents and cotangents. (5) Natural sines, cosines, tangents and cotangents. (6) Natural logarithms of numbers. (7) Exponential and Hyperbolic functions. (8) Trigonometric formulas. (9) Integrals.

J. M. Kinney.

A Brief Course in Advanced Algebra, by H. E. Buchanan, Professor of Mathematics, Tulane University, and Lloyd C. Emmons, Associate Professor of Mathematics, Michigan Agricultural College. Pages viii+185. 12x19.5 cm. 1925. Houghton Mifflin, Boston. $.88.

Students dislike a review of high school algebra which presents nothing new. For that reason the authors of this algebra have kept new material before the student throughout the text. The book is written from the modern point of view in that the notion of functionality is stressed. The derivative is introduced in connection with the qudratic equation and is used in the study of the polynomial.

The book may be used either in the fourth year of the high school or in the first year of college.

J. M. Kinney.

An Arithmetic for Teachers, by W. F. Roantree and Mary S. Taylor. Pages xiii+621. 14x19.5 cm. 1925. Macmillan.

Many teachers of arithmetic have no broader view of the subject than that presented in the texts they are teaching. It is also true that many have had little or no training in the method of presenting the subject to children.

The authors of the book under review have written a text which will be invaluable to teachers with limited training. They have provided in one volume (1) a book of information on the various items taught in arithmetic, a teacher's knowledge of the subject, and (2) a discussion of methods of presenting this knowledge to the child. The book will, no doubt, also be welcomed by the departments of mathematics in the teachers colleges, as a text-book.

J. M. Kinney.

Everyday Algebra, by H. C. Barber, Teacher of Mathematics in the English High School and Eliot Intermediate School, Boston, and Supervisor of Mathematics in the Public Schools in Newton, Mass. Pages xii+372. 13.5x19.5 cm. 1925. Houghton Mifflin. Price, $1.24.

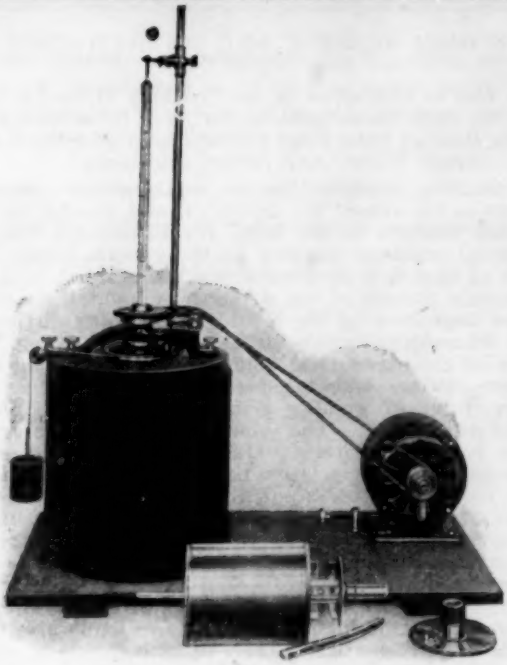
Teachers who have caught the spirit of the report of the National Committee on Mathematical Requirements will be pleased to see this text which embodies that spirit. It sets forth the modern point of view that algebra should be a living thing, that it should lead the pupil to feel and see that mathematics holds a very important position in the world of affairs. A great deal might be written in regard to the contents of the book but the reader should get it first hand by examining the book itself.

J. M. Kinney.

College Geometry, by Nathan Altshiller-Court, Associate Professor of Mathematics, University of Oklahoma. Pages xiii+254. 16x24 cm. 1925. Johnson Publishing Company, Richmond, Va.

In the elementary schools there are many teachers of arithmetic who know little of the subject beyond the material found in the text which they are teaching. A similar statement can be made concerning many teachers of geometry in the high school. This book will appeal to geometry teachers who wish to obtain a knowledge of the many modern theorems of plane Euclidean geometry. It is attractively written and, while it is intended as a text for college juniors or seniors it may be read by anyone, who has had a course in high school algebra and geometry.

J. M. Kinney.



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